CONNECTICUT RIVER BASIN

HANOVER, NEW HAMPSHIRE

HANOVER CENTER RESERVOIR DAM

NH 00051

STATE NO 108.14

PHASE I INSPECTION REPORT

NATIONAL DAM INSPECTION PROGRAM

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS. 02154

APRIL 1979

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KEY WORDS (Continue on reverse side if necessary and identify by block number)

DAMS, INSPECTION, DAM SAFETY,

Connecticut River Basin
Hanover New Hampshire
North Branch Mink Brook

ABSTRACT (Continue on reverse side if necessary and identify by block number)

The dam has a hydraulic height of 30 ft. and a length of 943 ft. Maximum storage capacity is about 476 ft. The dam embankment and qppurtenant structures are in good condition. It is small in size with a high hazard classification. A major breach at top of da could result in the loss of more than 10 lives and excessive property damage.

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DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02154

REPLY TO
ATTENTION OF:
NEDED

OCT 31 1979

Honorable Hugh J. Gallen
Governor of the State of New Hampshire
State House
Concord, New Hampshire 03301

Dear Governor Gallen:

Inclosed is a copy of the Hanover Center Reservoir Dam Phase I Inspection Report, which was prepared under the National Program for Inspection of Non-Federal Dams. This report is presented for your use and is based upon a visual inspection, a review of the past performance and a brief hydrological study of the dam. A brief assessment is included at the beginning of the report. I have approved the report and support the findings and recommendations described in Section 7 and ask that you keep me informed of the actions taken to implement them. This follow-up action is a vitally important part of this program.

A copy of this report has been forwarded to the Water Resources Board, the cooperating agency for the State of New Hampshire. In addition, a copy of the report has also been furnished the owner, Hanover Water Works Company.

Copies of this report will be made available to the public, upon request, by this office under the Freedom of Information Act. In the case of this report the release date will be thirty days from the date of this letter.

I wish to take this opportunity to thank you and the Water Resources Board for your cooperation in carrying out this program.

Sincerely,

M. B. Scheider

MAX B. SCHEIDER
Colonel, Corps of Engineers
Division Engineer

Incl
As stated

457-440

NATIONAL DAM INSPECTION PROGRAM
PHASE I INSPECTION REPORT

Identification No.:	NH00051
Name of Dam:	Hanover Center Dam
Town:	Hanover
County and State:	Grafton County, New Hampshire
Stream:	North Branch Mink Brook
Date of Inspection:	November 9, 1978

BRIEF ASSESSMENT

The Hanover Center Dam has a hydraulic height of 30 feet, a 14-foot topwidth, sideslopes of 2H:1V, and a length of 943 feet. It is an earthen embankment with a concrete chute-type spillway.

The dam spans a reach of the North Branch Mink Brook, and is located in west central New Hampshire. Maximum storage capacity is about 476 acre-feet. Hanover Center Dam is used for water supply for the Town of Hanover, New Hampshire. The pond is about 2000 feet in length with a surface area of about 33 acres.

The dam embankment and appurtenant structures are in good condition. However, because of an inadequate spillway, the overall rating is fair.

Based on small size and high hazard classifications in accordance with Corps guidelines, the test flood is 1/2 Probable Maximum Flood (PMF). With stoplogs in place, a test flood outflow of 2360 cfs (1275 csm) would overtop the dam by about 0.8 foot. The spillway will pass 800 cfs or about 34 percent of the test flood. With stoplogs removed, the test flood outflow would overtop the dam by about 0.6 foot while the spillway would pass 1320 cfs or about 56 percent of the test flood. A major breach at top of dam could result in the loss of more than 10 lives and excessive property damage.

The owner, Hanover Water Works Company, should implement the results of the recommendations and remedial measures given in Sections 7.2 and 7.3 respectively, within 1 year, except as noted, after receipt of this Phase I inspection report.

Warren A. Guinan

Warren A. Guinan
Project Manager
N.H. P.E. 2339

This Phase I Inspection Report on Hanover Center Reservoir Dam has been reviewed by the undersigned Review Board members. In our opinion, the reported findings, conclusions, and recommendations are consistent with the Recommended Guidelines for Safety Inspection of Dams, and with good engineering judgment and practice, and is hereby submitted for approval.

Joseph A. McElroy

JOSEPH A. MCELROY, MEMBER
Foundation & Materials Branch
Engineering Division

Carney M. Terzian

CARNEY M. TERZIAN, MEMBER
Design Branch
Engineering Division

Joseph W. Finegan, Jr.

JOSEPH W. FINEGAN, JR., CHAIRMAN
Chief, Reservoir Control Center
Water Control Branch
Engineering Division

APPROVAL RECOMMENDED:

Joe B. Fryar

JOE B. FRYAR
Chief, Engineering Division

PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I investigations. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D.C. 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the Spillway Test flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. Because of the magnitude and rarity of such a storm event, a finding that a spillway will not pass the test flood should not be interpreted as necessarily posing a highly inadequate condition. The test flood provides a measure of relative spillway capacity and serves as an aid in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

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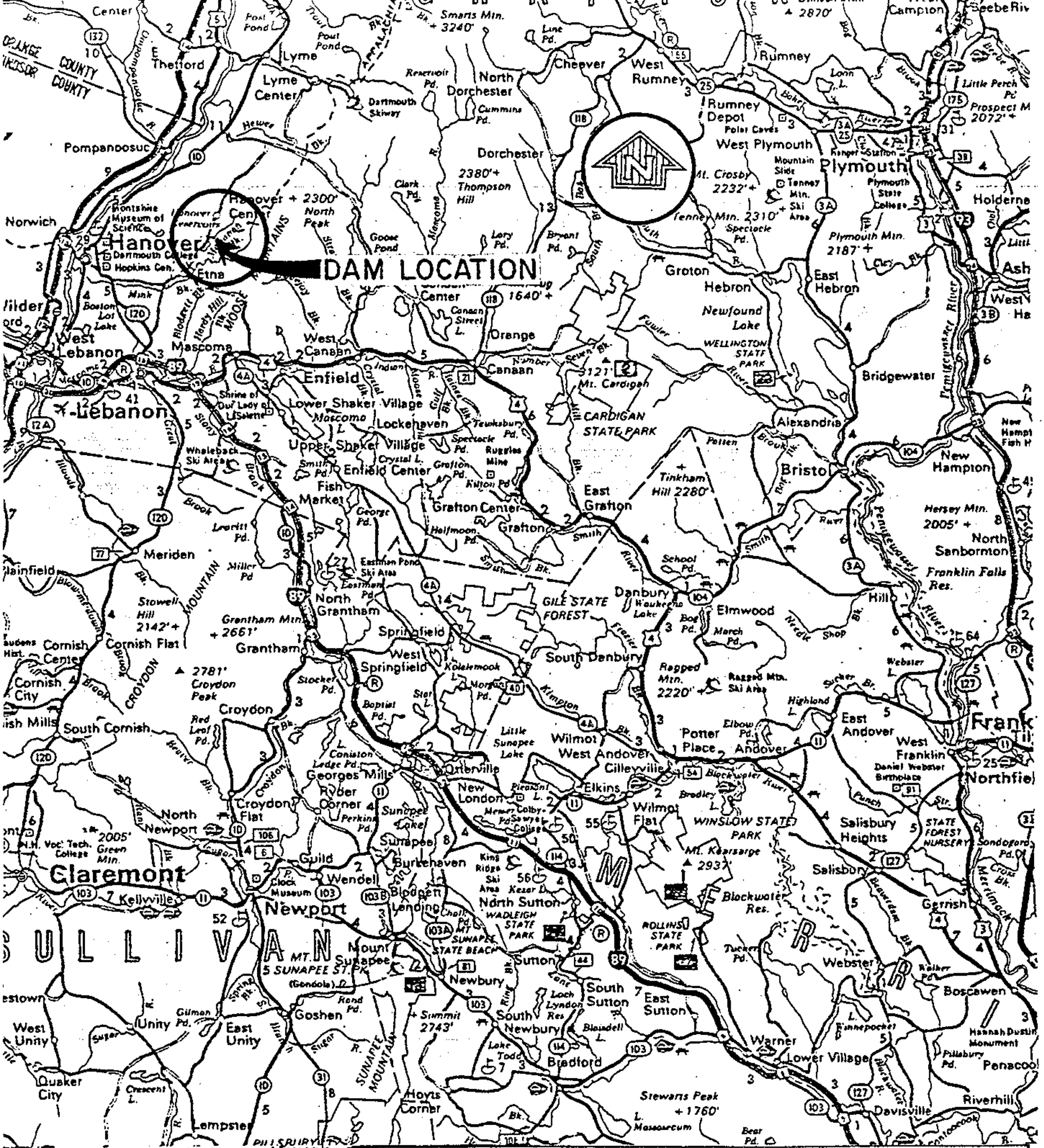
Figure 1 - Overview of Hanover Center Dam.



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SCALE IN MILES

0 5 10

BASED ON STATE OF NEW HAMPSHIRE
CIAL HIGHWAY MAP.

Anderson-Nichols & Co., Inc. CONCORD NEW HAMPSHIRE	U.S. ARMY ENGINEER DIV. NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASS.

NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

HANOVER CENTER DAM LOCATION MAP

N. BR. MINK BROOK NEW HAMPSHIRE

SCALE: SEE BAR SCALE

DATE: APRIL, 1979

NATIONAL DAM INSPECTION PROGRAM
PHASE I INSPECTION REPORT
HANOVER CENTER DAM

SECTION I
PROJECT INFORMATION

1.1 General

a. Authority. Public Law 92-367, August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a National Program of Dam Inspection throughout the United States. The New England Division of the Crops of Engineers has been assigned the responsibility of supervising the inspection of dams within the New England Region. Anderson-Nichols & Company, Inc. has been retained by the New England Division to inspect and report on selected dams in the State of New Hampshire. Authorization and notice to proceed were issued to Anderson-Nichols under a letter of November 20, 1978 from Max B. Scheider, Colonel, Corps of Engineers. Contract No. DACW33-79-C-0009 has been assigned by the Corps of Engineers for this work.

b. Purpose

(1) To perform technical inspection and evaluation of non-Federal dams to identify conditions which threaten the public safety and thus permit correction in a timely manner by non-Federal interests.

(2) To encourage and prepare the States to initiate quickly, effective dam safety programs for non-Federal dams.

(3) To update, verify, and complete the National Inventory of Dams.

1.2 Description of Project

a. Location. Hanover Center Dam is located in the Town of Hanover, New Hampshire. The dam spans the North Branch Mink Brook, a minor tributary of Mink Brook in the Connecticut River Basin. The dam is about 1.4 miles above the confluence with Mink Brook. The location of the dam is on U.S.G.S. Quadrangle, Mascoma, New Hampshire - Vermont with coordinates approximately at N43° 42' 42", W72° 12' 6", Grafton County, New Hampshire. (See Location Map page vii.)

b. Description of Dam and Appurtenances. Hanover Center Dam impounds the secondary water supply reservoir for the Town of Hanover. The dam consists of an earthen embankment with a concrete lined channel, a wooden stoplog section, and a concrete box chute-type spillway. The dam is about 943 feet long, 30 feet high, and 14 feet wide at the crest. (See Appendix B.) The upstream and downstream faces of the dam have sideslopes of 2H:1V. From south to north, the dam consists of an earthen embankment about 612 feet long with an average height of 10 feet, a 6.5-foot wide concrete chute spillway with a 20-foot wide inlet that houses 5 stoplog bays, a section of earth embankment 210 feet long that varies from 21 to 30 feet in height, and a 101-foot section of earth embankment that ends at natural ground. A valve house is located 100 feet to the south of the north abutment.

c. Size Classification. Small (Hydraulic height - 30 feet; storage - 476 acre-feet), based on height and storage ($<$ 40 feet and $\geq$ 50 to $<$ 1000 acre-feet) as given in Recommended Guidelines for Safety Inspection of Dams.

d. Hazard Classification. High Hazard. A major breach in the dam could probably result in the loss of more than 10 lives and cause excessive property damage. (See Section 5.1 f.)

e. Ownership. Hanover Center Dam is owned by the Hanover Water Works Company.

f. Operator. The Hanover Water Works Company, 47 South Main Street, Hanover, New Hampshire, 03755, is responsible for the operation of the Hanover Center Dam. Phone (603) 643-3439.

g. Purpose of Dam. The dam impounding the Hanover Center Reservoir was constructed to provide a backup water supply for the Town of Hanover.

h. Design and Construction History. The Hanover Center Dam was designed and built in 1961. A complete set of design plans was obtained from the files of Anderson-Nichols.

i. Normal Operational Procedures. The Hanover Center Reservoir is controlled by discharge through the Hanover Center Dam. Normal pool elevation is $1000^{\pm}$ MSL. The reservoir level is controlled by releasing water through the 10-inch water supply line to Reservoir No. 2 downstream. This line is flushed at least once a year, at which time the condition of all valves is checked. The stoplogs may be dropped by releasing the needle beams. However, Hanover Water Works stated that no stoplog lifting mechanism exists at Hanover Center Dam. Therefore, the original operating procedures listed on Pages B-4 and B-5 no longer apply.

1.3 Pertinent Data

a. Drainage Area. The drainage area consists of 1.85 square miles (1184 acres) of mountainous, predominantly wooded terrain.

b. Discharge at Damsite

(1) Outlet works (conduits) - one low-level outlet. Capacity at top of dam - 13 cfs @ 1005.0' MSL.

(2) The maximum discharge at the damsite is unknown. No records of past overtopping were disclosed.

(3) Ungated spillway capacity @ top of dam - not applicable

(4) Ungated spillway capacity @ test flood elevation - not applicable

(5) Gated spillway capacity @ top of dam - with stoplogs - 800 cfs @ 1005.0' MSL; without stoplogs - 1320 cfs @ 1005.0' MSL

(6) Gated spillway capacity @ test flood elevation - with stoplogs - 899 cfs @ 1005.8' MSL; without stoplogs - 1371 cfs @ 1005.8' MSL

(7) Total spillway capacity @ test flood elevation - with stoplogs - 899 cfs @ 1005.8' MSL; without stoplogs - 1371 cfs @ 1005.8' MSL

(8) Total project discharge @ test flood elevation - with stoplogs - 2360 cfs @ 1005.8' MSL; without stoplogs - 2360 cfs @ 1005.6' MSL

c. Elevation. (ft. above MSL based on elevation of 992.50 shown on dam plans for spillway crest elevation)

(1) Streambed at centerline of dam - 974.8 (downstream toe)

(2) Maximum tailwater - unknown

(3) Upstream invert low-level outlet - 979.5

(4) Recreation pool - not applicable

(5) Full flood control pool - not applicable

(6) Spillway crest - 992.5 (assuming all stoplogs removed)

(7) Design surcharge (original design) - unknown

(8) Top of dam - 1005.0

(9) Test flood pool - 1005.8

d. <u>Reservoir</u> (miles)

(1) Length of Maximum pool - 0.4

(2) Length of pool at normal pool - 0.4

(3) Length of flood control pool - not applicable

e. <u>Storage</u> (acre-feet)

(1) Recreation pool - not applicable

(2) Flood control pool - not applicable

(3) Normal pool - 298

(4) Top of dam - 476

(5) Test flood pool - 502

f. <u>Reservoir Surface</u> (acres)

(1) Recreation pool - not applicable

(2) Flood control pool - not applicable

(3) Normal pool - 33 (approximate)

(4) Test flood pool - 39 (approximate)

(5) Top of dam - 38 (approximate)

g. <u>Dam</u>

(1) Type - earthen embankment

(2) Length - 943' (design)

(3) Height - 30' (structural height)

(4) Sideslopes - 2H:1V U/S and D/S

(5) Topwidth - 14'

(6) Zoning - Impervious core and random pervious fill (See Appendix B - Sketches)

(7) Impervious Core - Plans show a core with an 11' topwidth; 2H:1V sideslope upstream, and a 1H:2V sideslope downstream.

(8) Cutoff - Plans indicate 10' wide 3' deep cutoff trench.

(9) Grout curtain - unknown (Plans show that a grout curtain may have been necessary in the bedrock at the north end of the dam.)

h. Diversion and Regulating Tunnel. not applicable

i. Spillway

(1) Type - concrete chute

(2) Length of weir - 18'; tapers to 6 1/2' wide chute 20 feet downstream of stoplogs.

(3) Crest elevation - 992.5 (without stoplogs); 1000.0 (with stoplogs)

(4) Gates - stoplogs (5 bays)

(5) U/S Channel - Hanover Center Reservoir, open, sand and gravel approach channel. The banks surrounding the reservoir have an average slope of 8H:1V. The shore is lined with brush and trees.

(6) D/S Channel - the channel downstream of the spillway is a narrow brook. The streambed is rocky and the valley sides are covered with trees. Immediately downstream of the dam north of the spillway is a small fish pond; the pond empties into the same brook, upstream of the spillway outlet. This small pond assures a minimum water level downstream of the dam to maintain fish life.

j. Regulating Outlets. The primary outlet is a concrete chute spillway that is controlled by stoplogs in 5 bays. Hanover Water Works reported that the stoplogs may be dropped by releasing the needle beams. The stoplogs have remained in place since construction. The cross section at the stoplogs is an 18-foot rectangular section which tapers to 6½ feet wide 20 feet downstream of the stoplogs. A 110-foot long chute discharges into the North

Branch Mink Brook just below the small pond. A 24-inch cast iron pipe passes through the dam. Connected to the pipe is a valve in the valve house located on the upstream side of the dam. The 24-inch pipe is reduced to a 10-inch cast iron pipe just downstream of the dam. A 10-inch tee connects one leg to a 10-inch water-supply line. The other leg of the tee is a 10-inch line that discharges into the fish pond. A control valve is located over the tee, enabling the operator to release flow through either or both lines. This mechanism could be utilized to lower the reservoir during an emergency.

SECTION 2
ENGINEERING DATA

2.1 Design

The dam was originally designed by Anderson-Nichols & Company, Inc. in 1961. The design plans were obtained from Anderson-Nichols' files (see Appendix B). No other design data were obtained for the dam.

2.2 Construction

The construction was done by Trumbull and Nelson, Hanover, New Hampshire.

2.3 Operation

No engineering operational data were disclosed.

2.4 Evaluation

a. Availability. Limited engineering data were available for the Hanover Center Dam. A search of the files of the New Hampshire Water Resources Board (NHWRB) revealed only a limited amount of recorded information. The design plans were obtained from Anderson-Nichols' files; no computations, design data, or other historical information were found.

b. Adequacy. The final assessments and recommendations of this investigation are based on the plans of the dam, the visual inspection, and the hydrologic and hydraulic calculations.

c. Validity. The plans disclosed are in conformity with the dam as seen on the visual inspection.

SECTION 3
VISUAL INSPECTION

3.1 Findings

a. General. Hanover Center Dam is a low dam which impounds a reservoir of small size. Its overall size classification is small. The watershed above the dam is mountainous and partially forested. The dam is located about 1½ miles upstream of the Village of Etna and about 6 miles upstream of the confluence of Mink Brook and the Connecticut River.

b. Dam. Hanover Center Dam is an earthen embankment, 30 feet high, 943 feet long, and 14 feet wide at the crest.

The upstream face of the dam (See Appendix C - Figure 2) has a slope of 2H:1V. At the time of the inspection, the water level in the reservoir was 12.3 feet below the crest of the dam. The portion of the upstream face that was visible above the water is covered with riprap that is in good condition. Some grass is growing up through the riprap between the normal pool elevation and the crest.

The crest of the dam (See Appendix C - Figure 3) is covered with grass from the south abutment to approximately the center of the dam. From the center of the dam to the north abutment there is a gravel roadway which services a small camp located on a natural knoll, downstream of the center of the dam. There is no vegetation in the two wheel tracks, but the remainder of the crest is covered with grass. The grass on the crest appears to have been mowed regularly. The camp occupant has recently tilled and seeded the roadway on the crest south of the spillway.

The downstream face of the dam (See Appendix C - Figure 4) has a slope of 2H:1V. The entire downstream face is covered with short grass. The downstream face of the dam between the north abutment and the natural knoll at the center of the valley is slightly uneven from approximately mid-height to the toe. It does not appear that this uneveness is the result of any seepage or stability problem. There is a rock drain at the downstream toe between the north abutment and the center knoll.

Brush has grown up along a fence which is parallel to and immediately downstream of the toe of the dam from the center knoll to the south abutment. Clearing of the brush has been started and was completed for about half the total length between the south abutment and the center knoll.

c. Appurtenant Structures.

(1) Stoplog Section and Discharge Conduit. A stoplog section overflow spillway and discharge conduit (See Appendix C - Figures 4 & 5) are located near the center of the dam, at the natural knoll. The intake channel is 24 feet wide at the mouth, with vertical concrete side walls (tapering down to 18 feet wide at the stoplog supports). The top of the stoplogs are 7.6 feet above the channel bottom. The stoplogs will remain in place indefinitely. (See p. 1-6, item j.) There are 5 stoplog sections approximately 3' 8" wide. The channel bottom is 12.5 feet below the crest of the dam. A 10-foot wide concrete service bridge crosses the channel. The design drawings, prepared by Anderson-Nichols & Company, Inc. in 1961, show two concrete cutoff walls across the bottom of the channel and up the sidewalls. A 6.5' wide, steeply sloping, chute-type concrete box channel approximately 110 feet long discharges to the downstream channel. The height of conduit varies from 6 feet to 11 feet. The concrete structure and stoplog supports were observed to be in good condition. Erosion of concrete is limited to the loss of surface laitance where in contact with water. All exposed steel associated with the chute spillway has been recently painted. The 3-inch thick wood stoplogs were also observed to be in good condition with no evidence of deterioration. Some leakage through the joints and slots was observed recently (24 April 1979). Some small cracks were visible in the concrete south wall at the downstream end of the chute spillway.

The service bridge and railings were also observed to be in good condition.

(2) Water Supply Valve Structure. A 10-foot square concrete structure that supports the valvehouse (See Appendix C - Figure 6) is located approximately 80 feet from the north end of the dam on the upstream face. The valves control flow into the Town of Hanover water supply system. The concrete structure was observed to be in good condition.

d. Reservoir Area. The reservoir (See Appendix C - Figure 7) extends about one-half mile upstream from the dam. Trees surround the shoreline. The northeast shoreline, which is about 150 feet from Hanover Center Road, parallels the road for about 700 feet. Because the water level was low at the time of the inspection, the bottom of the reservoir near the dam was exposed from a point near the spillway to the south abutment. It appears that only a minor amount of silt has accumulated in the reservoir since the dam was constructed in 1961.

e. Downstream Channel. The downstream channel is below the section of the dam between the north abutment and the center knoll. Immediately downstream of this section of the dam is a small fish pond impounded behind a man-made dam. The pond is fed by a 10-inch diameter cast iron tee extension, as well as a 4-inch by-pass line. The 4-inch line is used to maintain a minimum flow into the fish pond. A flow meter connected to the 4-inch line is located at the northern end of the dam near the crest on the downstream face. The chute spillway, near the center of the dam, discharges into the channel (See Appendix C - Figure 8) a short distance downstream of the fish pond dam. The floor of the channel is covered with cobbles and boulders. Brush overhangs the channel and some recently cut brush and trees are lying in the channel. A 12-inch diameter concrete pipe discharges into the brook just below the downstream end of the chute spillway. This concrete pipe channels water collected in a gutter at the downstream toe of the southern end of the dam to the brook.

3.2 Evaluation

Based on the visual inspection, Hanover Center Dam appears to be well maintained and in good condition. However, due to an inadequate spillway, the overall rating is fair.

As part of the routine maintenance and operating program, brush and trees should be cleared from the downstream channel. During future inspections of the dam, attention should be paid to the downstream slope of the dam between the north abutment and the center knoll to verify that the slightly uneven surface is not the result of any seepage or stability problem.

SECTION 4
OPERATIONAL PROCEDURES

4.1 Procedures

The Hanover Water Works Company has operated the reservoir since 1961. (See section 1.2 i. for operational procedures.)

4.2 Maintenance of Dam

The Hanover Water Works Company is responsible for the maintenance of the Hanover Center Dam. Maintenance is done on a regular basis.

4.3 Maintenance of Operating Facilities

The Hanover Water Works Company is responsible for maintaining the operating facilities.

4.4 Description of Any Warning System in Effect

No written warning system was disclosed for the Hanover Center Dam.

4.5 Evaluation

The present maintenance procedures are adequate to ensure that minor problems encountered could be remedied within a reasonable amount of time. The operating procedures should be modified to incorporate periodic testing of the needle beams.

SECTION 5
HYDROLOGIC/HYDRAULIC

5.1 Evaluation of Features

a. General. The Hanover Center Dam is an earthen embankment with a concrete chute-type spillway which impounds a small water supply reservoir. The total length of the dam is 943 feet, 18 feet of which consists of the concrete spillway.

b. Design Data. No original hydrologic and hydraulic design data were found or disclosed for the dam.

c. Experience Data. No information regarding past overtopping of the structure was disclosed.

d. Visual Inspections. No visual evidence of overtopping such as damage to the structure was noted at the time of the inspection.

e. Test Flood Analysis. The Hanover Center Dam is classified as small, having a hydraulic height of 30 feet and a maximum storage capacity of 476 acre-feet. This small reservoir contains runoff from a 1.85 square mile drainage area, characterized by mountainous, mostly forested terrain. Using a CSM value of 2550, a Probable Maximum Flood (PMF) of 4718 cfs was obtained. The Recommended Guidelines for Safety Inspection of Dams dictated use of ½ the PMF.

Using ½ PMF, the test flood discharge was determined to be 2360 cfs. The overtopping analysis indicates that, with stoplogs in place, the dam would be overtopped by 0.8 foot during the test flood. The maximum spillway capacity at top of dam is 800 cfs which is 34% of the test flood discharge. With stoplogs removed, the dam would be overtopped by 0.6 foot during the test flood. The maximum spillway capacity at top of dam would be 1320 cfs which is 56% of the test flood discharge. It is likely that the stoplogs would be in place because of the difficulty of removing the pins holding the needle beams. (see p. 1-6, item j.)

f. Dam Failure Analysis. The impace of failure of the dam at top of dam was assessed using the Guidance for Estimated Downstream Dam Failure Hydrographs issued by the Corps of Engineers. The analysis covered the downstream reach extending from the dam to a group of houses north of the Village of Etna, a distance of about 5,900 feet. A breach at top of dam would result in inundation of Hanover Center Road at two brook crossings, as well as wash out a sand and gravel driveway just downstream of the dam. Six houses would be subject to a 9.6-foot increase in stage above the already high 4.0-foot tailwater elevation, inundating them with more than six feet of water. Excessive property damage could result and more than 10 lives would probably be lost.

SECTION 6
STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. Visual Observations. The visual inspection indicated that the dam embankment and appurtenant features are well-maintained and in good condition; however, because of inadequate spillway capacity, the condition of the structure is considered fair. No evidence of seepage or slope instability were observed; evidence of trespassing was minimal.

Standing water was observed in a shallow, small depression near the downstream toe between the south abutment and the center knoll, but no water was being discharged. It appears that the standing water is not the result of seepage from the reservoir.

A slight uneveness of the downstream slope of the dam between the south abutment and the center knoll was noted. It does not appear that this uneveness is the result of any seepage or stability problem.

b. Design and Construction Data. A complete set of design drawings is available. They show that: the dam is founded on glacial till; the central portion and upstream shell of the embankment consist of selected impervious fill; the downstream shell consists of random pervious fill; the upstream face is covered with a 15-inch layer of dumped-rock riprap placed on a 9-inch layer of gravel bedding; a horizontal gravel drainage blanket is placed beneath the downstream shell; a rock toe drain is located at the downstream toe of the dam; a graded filter is between the toe drain and the random pervious fill of the downstream shell; and 6-inch perforated seepage drains are beneath the downstream toe of the dam. The outlets of the two seepage drains between the north abutment and the center knoll were not observed during the inspection; the outlet of the drain between the south abutment and the center knoll was observed; no water was discharging from it.

c. Operating Records. No operating records pertinent to the structural stability of the dam were disclosed. See Section 4 for operating procedures performed by the owner.

d. Post-Construction Changes. No changes appear to have been made since the original construction of the dam.

e. Seismic Stability. This dam is located in Seismic Zone 2 and in accordance with the recommended Phase I guidelines does not warrant seismic analysis.

SECTION 7
ASSESSMENT, RECOMMENDATIONS AND REMEDIAL MEASURES

7.1 Dam Assessment

a. Condition. The evaluation and visual inspection indicate that Hanover Center Dam is in fair condition. However, the capacity of the spillway is inadequate as discussed in Section 5.

A minor uneveness of the downstream slope and a shallow, small depression with standing water near the downstream toe were observed, but neither condition appears to be related to either a seepage or stability problem. Brush is overhanging the discharge channel and some cut brush and felled trees were noted in the discharge channel.

b. Adequacy of Information. The information available is adequate to assess the condition of the dam. The conclusions about the stability of the dam are based primarily on the results of the visual inspection and a review of the design plans.

c. Urgency. The operating and maintenance recommendations made in 7.3 a. below should be implemented within 1 year after receipt of this Phase I report.

d. Need for Additional Investigation. No additional investigation is required.

7.2 Recommendations

The owner should engage a Registered Professional Engineer to further investigate the adequacy of the spillway capacity, the feasibility of providing an additional emergency spillway and a remote-controlled automated pin release for the stoplog needle beams.

7.3 Remedial Measures

a. Operating and Maintenance Procedures. The owner should:

(1) Keep the brush cut near the downstream toe of the dam between the south abutment and the center knoll.

(2) Clear the brush and trees along the discharge channel for a distance of 20 feet on either side of the channel and for a distance of 100 feet downstream from the fish pond dam or to the limits of the town-owned property, whichever is less.

(3) Inspect the dam monthly.

(4) Engage a Registered Professional Engineer to make a comprehensive inspection once every two years.

(5) Establish written operational and maintenance procedures.

(6) Establish a surveillance program for use during and immediately following periods of heavy rainfall, and also a warning program to follow in case of emergency conditions.

7.4 Alternatives

None.

APPENDIX A

VISUAL INSPECTION CHECKLIST

VISUAL INSPECTION CHECKLIST
PARTY ORGANIZATION

PROJECT Hanover Center Dam, N.H.

DATE November 9, 1978

TIME 1:00 P.M.

WEATHER Cool, sunny

W.S. ELEV.	U.S.	DN.S.
	992.7	974.8

PARTY:

1. Robert Langen
2. Stephen Gilman
3. Douglas Ford
4. Robert Ojendyk
5. Ronald Hirschfeld
6. Warren Guinan
7.
8.
9.
10.

	PROJECT FEATURE	INSPECTED BY	REMARKS
1.	Hydrology/Hydraulics	R. Langen/D. Ford	
2.	Structural Stability	S. Gilman	
3.	Soils & Geology	R. Hirschfeld	
4.			
5.			
6.			
7.			
8.			
9.			
10.			

PERIODIC INSPECTION CHECKLIST

PROJECT Hanover Center Dam, N.H. DATE November 9, 197

PROJECT FEATURE Dam Embankment NAME ____________

DISCIPLINE ____________ NAME ____________

AREA EVALUATED	CONDITION
DAM EMBANKMENT	
Crest Elevation	1005.0' MSL
Current Pool Elevation	992.7' MSL
Maximum Impoundment to Date	15" above stoplogs
Surface Cracks	None apparent
Pavement Condition	Not paved
Movement or Settlement of Crest	None apparent
Lateral Movement	None apparent
Vertical Alignment	Good
Horizontal Alignment	Good
Condition at Abutment and at Concrete Structures	Good
Indications of Movement of Structural Items on Slopes	None apparent
Trespassing on Slopes	None apparent
Sloughing or Erosion of Slopes or Abutments	Downstream slope of north section embankment is slightly uneven frc about mid-height to toe.
Rock Slope Protection - Riprap Failures	Riprap on upstream face in good condition.
Unusual Movement or Cracking at or Near Toe	None apparent
Unusual Embankment or Downstream Seepage	None apparent. Some standing wat in closed depression at downstrea toe of south section.
Piping or Boils	None apparent
Foundation Drainage Features	Plans show drains beneath downst half of embankment. Drains were observed during inspection of roc at downstream toe of north sectic of dam.
Toe Drains	
Instrumentation System	None
Vegetation	Grass on crest and downstream slc riprap on upstream slope.

PERIODIC INSPECTION CHECKLIST

OJECT Hanover Center Dam, N.H. DATE November 9, 1978

OJECT FEATURE Intake Channel & Structure NAME

SCIPLINE NAME

AREA EVALUATED	CONDITION
<u>TLET WORKS - INTAKE CHANNEL AND INTAKE STRUCTURE</u>	
Approach Channel	
Slope Conditions	No slopes
Bottom Conditions	Soil bottom of reservoir
Rock Slides or Falls	None
Log Boom	None
Debris	None
Condition of Concrete Lining	Not visible
Drains or Weep Holes	None
Intake Structure	Not visible
Condition of Concrete	
Stop Logs and Slots	

PERIODIC INSPECTION CHECKLIST

PROJECT Hanover Center Dam, N.H. DATE November 9, 1978

PROJECT FEATURE Control Tower NAME ____________

DISCIPLINE ____________ NAME ____________

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - CONTROL TOWER</u>	
a. Concrete and Structural	
General Condition	Good to excellent
Condition of Joints	Good
Spalling	None
Visible Reinforcing	None
Rusting or Staining of Concrete	None
Any Seepage or Efflorescence	None visible
Joint Alignment	Good
Unusual Seepage or Leaks in Gate Chamber	None visible
Cracks	None visible
Rusting or Corrosion of Steel	None visible
b. Mechanical and Electrical	
Air Vents	Not applicable
Float Wells	Not applicable
Crane Hoist	Not applicable
Elevator	Not applicable
Hydraulic System	Not applicable Not applicable
Service Gates	Not applicable
Emergency Gates	Not applicable
Lightning Protection System	Not applicable
Emergency Power System	Not applicable
Wiring and Lighting System	Not applicable

PERIOD INSPECTION CHECKLIST

PROJECT Hanover Center Dam, N.H. DATE November 9, 1978

PROJECT FEATURE Outlet Works NAME

DISCIPLINE NAME

AREA EVALUATED	CONDITION
OUTLET WORKS - TRANSITION AND CONDUIT	Stoplog spillway outlet
General Condition of Concrete	Good
Rust or Staining on Concrete	None visible
Spalling	None visible
Erosion or Cavitation	None visible
Cracking	None visible
Alignment of Monoliths	Good
Alignment of Joints	Good
Numbering of Monoliths	
Stoplog supports	Steel in contact with water is rusted, original paint gone, steel above water-painted, in good condition.

PERIODIC INSPECTION CHECKLIST

PROJECT Hanover Center Dam, N.H. DATE November 9, 1978

PROJECT FEATURE Outlet Works NAME

DISCIPLINE NAME

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - OUTLET STRUCTURE AND OUTLET CHANNEL</u>	
General Condition of Concrete	Good
Rust or Staining	None visible
Spalling	None visible
Erosion or Cavitation	None visible
Visible Reinforcing	None
Any Seepage or Efflorescence	None
Condition at Joints	Good
Drain holes	None
Channel	Good
Loose Rock or Trees Overhanging Channel	None
Condition of Discharge Channel	Good

PERIODIC INSPECTION CHECKLIST

PROJECT Hanover Center Dam, N.H. DATE November 9, 1978

PROJECT FEATURE Chute spillway NAME

DISCIPLINE NAME

AREA EVALUATED	CONDITION
OUTLET WORKS - SPILLWAY WEIR, APPROACH AND DISCHARGE CHANNELS	
. Approach Channel	
General Condition	Good
Loose Rock Overhanging Channel	None
Trees Overhanging Channel	None
Floor of Approach Channel	Soil bottom of reservoir
. Weir and Training Walls	
General Condition of Concrete	Good
Rust or Staining	None visible
Spalling	None visible
Any Visible Reinforcing	None
Any Seepage or Efflorescence	None
Drain Holes	None
. Discharge Channel	
General Condition	Fair
Loose Rock Overhanging Channel	None
Trees Overhanging Channel	Brush overhanging channel
Floor of Channel	Cobbles and boulders
Other Obstructions	Some recently cut trees and brush lying in channel. Culvert 500 ft. downstream.

PERIODIC INSPECTION CHECKLIST

PROJECT Hanover Center Dam, N.H. DATE November 9, 1978

PROJECT FEATURE Service Bridge for Valve-house NAME

DISCIPLINE NAME

AREA EVALUATED	CONDITION
OUTLET WORKS - SERVICE BRIDGE	
a. Super Structure	
Bearings	Not applicable
Anchor Bolts	Not applicable
Bridge Seat	Good
Longitudinal Members	Good
Underside of Deck	
Secondary Bracing	
Deck	Treated wood - good
Drainage System	None
Railings	None
Expansion Joints	None
Paint	Good
b. Abutment & Piers	Not applicable
General Condition of Concrete	
Alignment of Abutment	
Approach to Bridge	
Condition of Seat & Backwall	

PERIODIC INSPECTION CHECKLIST

PROJECT Hanover Center Dam, N.H. DATE November 9, 1978

PROJECT FEATURE Service Bridge for Spillway NAME

DISCIPLINE NAME

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - SERVICE BRIDGE</u>	
a. Super Structure	
Bearings	Not applicable
Anchor Bolts	Not applicable
Bridge Seat	Concrete - good
Longitudinal Members	
Underside of Deck	
Secondary Bracing	
Deck	Concrete - good
Drainage System	None
Railings	Good
Expansion Joints	None
Paint	Good
b. Abutment & Piers	
General Condition of Concrete	Good
Alignment of Abutment	Good
Approach to Bridge	Good
Condition of Seat & Backwall	Good

PROJECT Hanover Center Dam, NH

DATE November 9, 1978

PROJECT FEATURE Reservoir

NAME R. Langen

AREA EVALUATED	REMARKS
Stability of Shoreline	Good
Sedimentation	Minor
Changes in Watershed Runoff Potential	None
Upstream Hazards	None
Downstream Hazards	Houses adjacent to stream 1 downstream; two road crossir
Alert Facilities	None posted
Hydrometeorological Gages	None
Operational & Maintenance Regulations	None posted

APPENDIX B

ENGINEERING DATA

NEW HAMPSHIRE WATER RESOURCES BOARD

INSPECTION REPORT

wn: Hanover Dam Number:

me of Dam, Stream and/or Water Body:

ner: Hanover Water Works Telephone Number:

iling Address:

x. Height of Dam: 30' Pond Area: 32A Length of Dam: 940

UNDATION: Earth

TLET WORKS: 5 Stoplog Bays 18' total 4' Freeboard
7'6" deep

BUTMENTS:

MBANKMENT: Earth Embankment 12' Top 2:1 slopes

: Give Sizing, Condition and detailed description for each item, if applicable.

ILLWAY: Length: 18 Freeboard: 4

SEEPAGE: Location, estimated quantity, etc.

None

Changes Since Construction or Last Inspection:

Tail Water Conditions:

Overall Condition of Dam: Good

Contact With Owner: No

Date of Inspection: 9 June 77 Suggested Reinspection Date

Class of Dam: Menace B

Signature

Date

Note: Give Sizing, Condition and detailed description for each item, if applic

WATER RESOURCES BOARD

SITE EVALUATION DATA

ER: Hanover Water Works TELEPHONE NO.

LING ADDRESS:

E LOCATION (TOWN OR CITY) Hanover

E OF STREAM OR WATERBODY: No Br Mink Brook

DRANGLE: LOCATION

GHT OF (PROPOSED, EXISTING) DAM 30' LENGTH 940'

E OF (PROPOSED, EXISTING) STRUCTURE Earth Embankment

INAGE AREA 2 SM POND AREA 32 A

ILABLE ARTIFICIAL STORAGE: PERMANENT: TEMPORARY: TOTAL 298 AF

STING DEVELOPMENT DOWNSTREAM OF (PROPOSED, EXISTING) STRUCTURE Town Road

Several Houses

ENTIAL DEVELOPMENT DOWNSTREAM OF (PROPOSED, EXISTING) STRUCTURE

ENTIAL DAMAGE DOWNSTREAM OF STRUCTURE (EXPLAIN IN DETAIL AND INCLUDE ANY POTEN-
. LOSS OF LIFE: ESTIMATE)

ER COMMENTS:

S OF STRUCTURE -- ~~NON-MENACE:~~ MENACE R B C DAM # 108.14

OF INSPECTION: 9 June 77

SIGNED S Burritt

SIGNATURE

DATE:

ARCHITECTURAL ENGINEERS

ANDERSON-NICHOLS & Company, Inc.

A CO-ORDINATED ENGINEERING SERVICE

BOSTON, MASS.
150 CAUSEWAY STREET

CONCORD, N. H.
10 EASTMAN STREET

7 February 1961

FEB 8 1961
NEW HAMPSHIRE
WATER RESOURCES BOARD

Mr. Leonard R. Frost
Engineer, Water Resources Board
State House Annex
Concord, New Hampshire

SUBJECT: Hanover Center Reservoir Operation
Our Job C-1541

Dear Mr. Frost:

In your letter of 23 January 1961, you requested some informatio in regard to the procedure to be followed in the operation of the proposed reservoir at Hanover Center, to be constructed by the Hanover Water Works Company.

The drainage area of the proposed reservoir, as we have now determined it from the U.S. Geological Survey quadrangle sheet, is 1185 acres. The area of the reservoir at elevation 1000 is 32. acres, and the volume of the reservoir at elevation 1000 is 298 ac

I have discussed the proposed operation of the reservoir with Mr Fred Parker, who is acting as Superintendent of the Water Work Company since the death of Mr. Philip Coykendal, and Mr. J. R Gamble, Executive Vice-President of the Company. The operat rules for the reservoir which we have decided upon are as follow

1. Whenever the elevation of the water in the reservoir falls below the top of the stop logs in place in the chute spillway, the 4-inch by-pass valve in the 24-inch valve in the valve house shall be opened to permit flow to the brook below the dam. The discharge through the by-pass will not be required to exceed the inflow to the reservoir. *

"Al" Lewis suggests that a sentence be incl. clause stating "sufficient water shall to maintain fish life downstream".

2. The maximum elevation of the water carried in the reservoir about 1 March of any year shall not exceed 998.5, and at that time, the maximum elevation of the stop logs in place in the chute spillway shall not exceed 999.0. When the snow melt on the drainage area above the dam is about complete, the stop logs in all five bays may be replaced and the water in the reservoir allowed to rise, subject, however, to rules three and four herein.

3. Whenever the elevation of the water in the reservoir exceeds 1000.4, stop logs shall be removed from the chute spillway or water drawn through the pipe line, to control the reservoir water at elevation 1000.4 or lower.

4. Whenever the water in the reservoir is at elevation 1000 or higher, and there is a measured precipitation at Hanover, in any 24-hour period, in excess of one inch, stop logs shall be removed to control the water at elevation 1000 or lower as long as possible. If, after removal of as many stop logs as possible, the water in the reservoir rises above elevation 1000, a constant watch of the water elevation shall be made, and if it reaches 1002.5, needle beams shall be tripped as necessary to control the water at 1002.5 or lower. Timing of the tripping of successive meedle beams shall be such as to prevent undue rise in the discharge in the brook below the dam.

I believe this to be an acceptable set of reservoir operating rules.

THE STATE OF NEW HAMPSHIRE

County of Grafton ss. January 17 1

STATEMENT OF INTENT TO CONSTRUCT ~~OR~~

~~RECONSTRUCT~~ A DAM AT Hanover

TO THE WATER RESOURCES BOARD:

In compliance with the provisions of RSA 482:3.

We, Hanover Water Works Company
I, (Here state name of person or persons, partnership, association, corpor

etc.)

hereby state our intent to the Water Resources Board to construct, ~~to recon~~ ~~to make repairs to~~, a dam along, or (cross out portion not applicable) acro

North Branch of Mink Brook
(Here state name of stream or body of water)

At a point 1.5 miles north of Etna Village
(Here give location, by distance from mouth of stream, county

municipal boundary)

in the town (s) of Hanover

in accordance with PRELIMINARY PLANS, and SPECIFICATIONS FILED WITH THIS ST AND MADE A PART HEREOF.

We, ~~I,~~ understand that more detailed plans and specifications may be requ by the Board in conformance with RSA 482:4 and that, if such plans are requ construction will not commence until such plans have been filed with and ap by the Board.

The purpose of the proposed construction is Municipal Water
(Here briefly state use to

Supply
which stored water is to be put)

The construction will consist of an earth embankment
(Here give brief description of

dam equipped with a reinforced concrete chute spillway.
work contemplated including height of dam)

The dam will be approximately 940 feet long and the maximum height

will be about 30 feet.

All land to be flowed ~~is not~~ is owned by applicant.

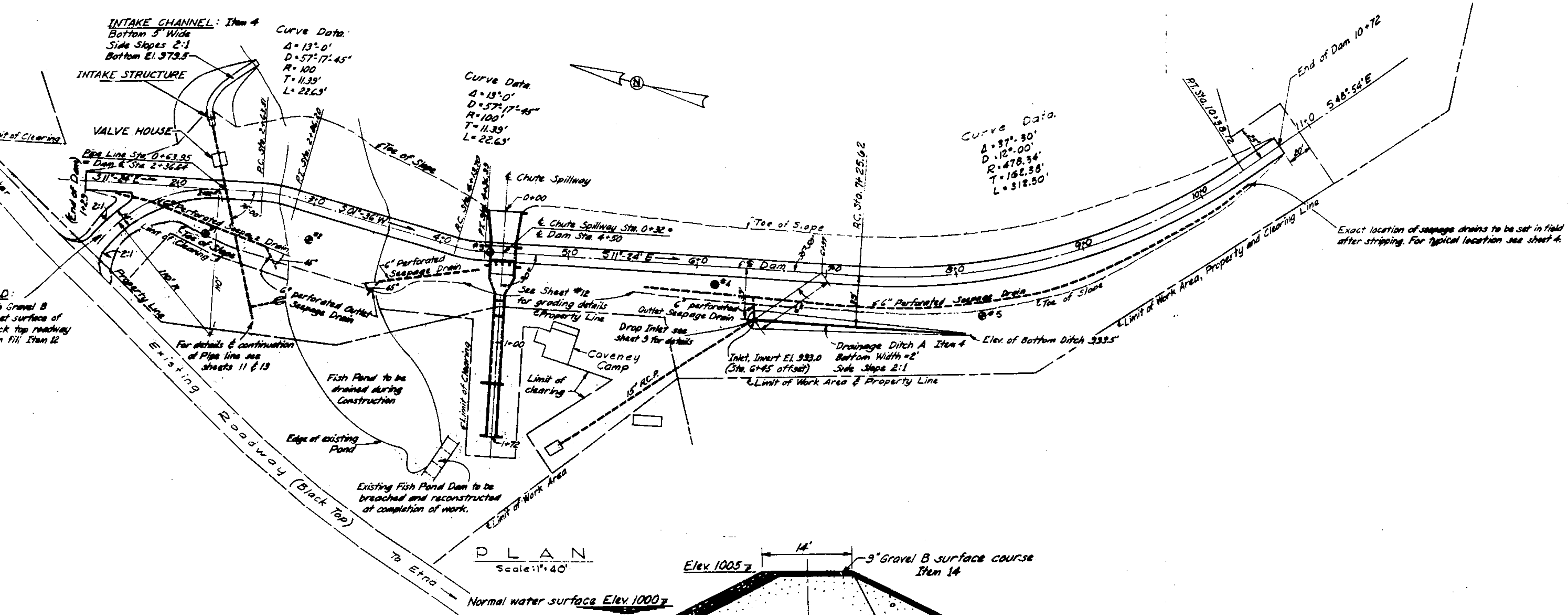
Hanover Water Works Company

By [signature]
J. Ross Gamble, Executive Vice Pres

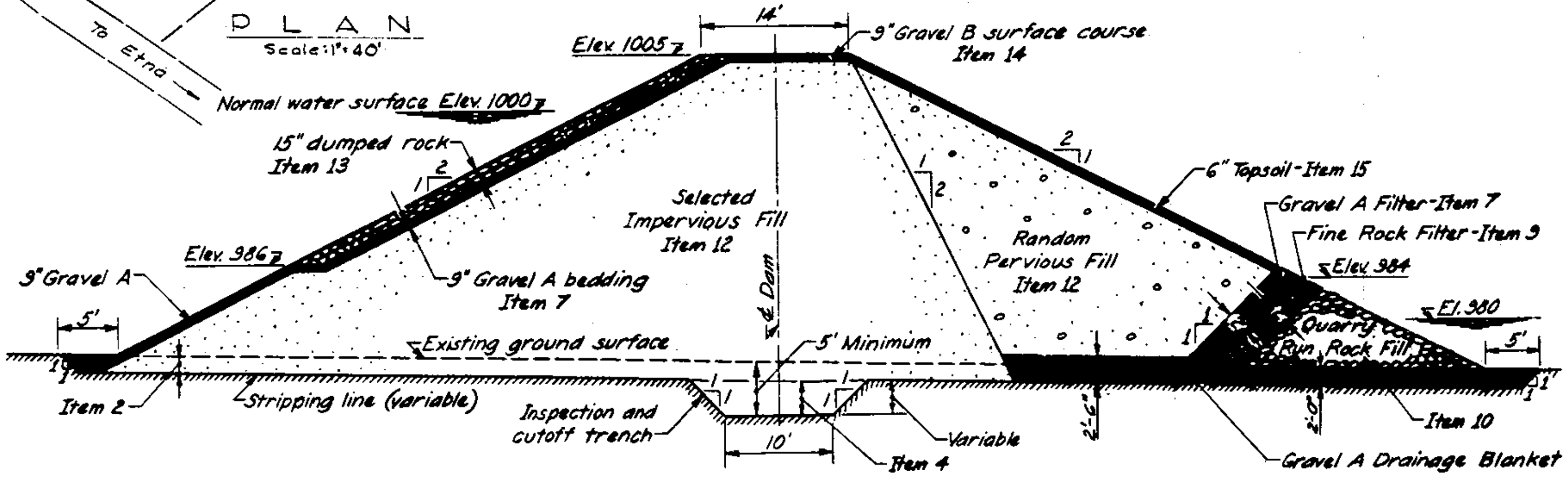
Address Precinct Building

Hanover, New Hampshire

Note: This statement together with plans, specifications and information and data filed in connection herewith will remain on file in the office of the Water Resources Board. This statement is to be filed in duplicate.

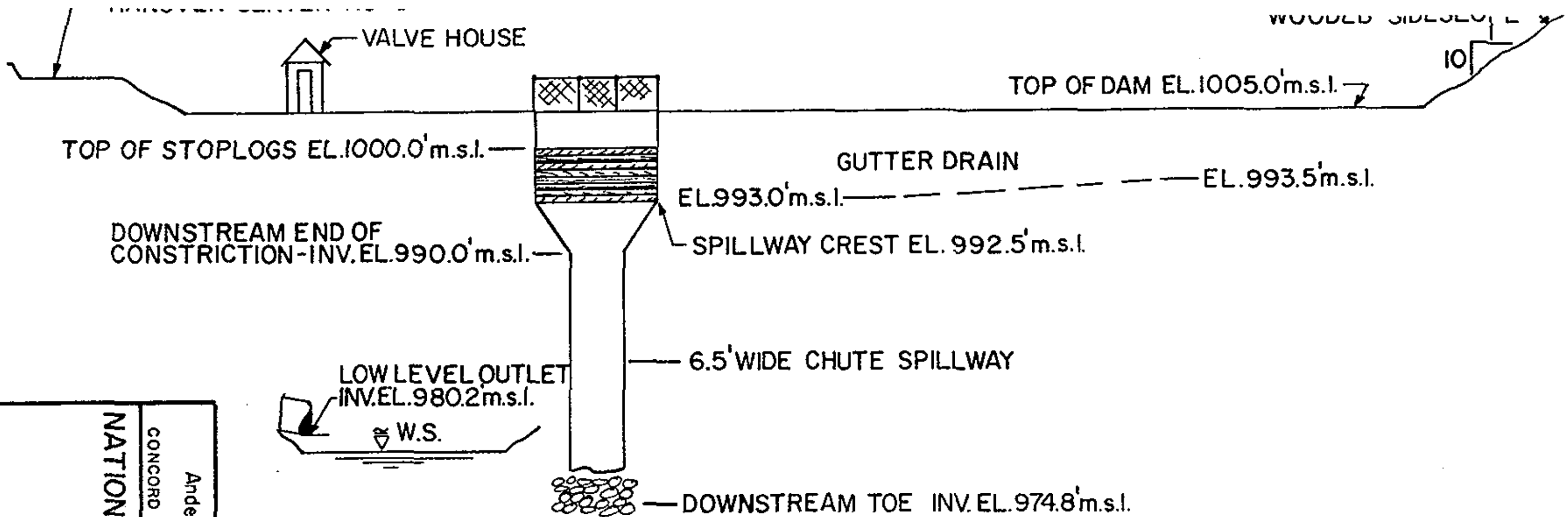


PLAN
Scale: 1"=40'



EMBANKMENT CROSS-SECTION BETWEEN STA. 2+50± & 3+70±

SCALE: 1"=10'



ELEVATION

Anderson-Nichols & Co., Inc.
CONCORD NEW HAMPSHIRE

U.S. ARMY ENGINEER DIV. NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

HANOVER CENTER DAM

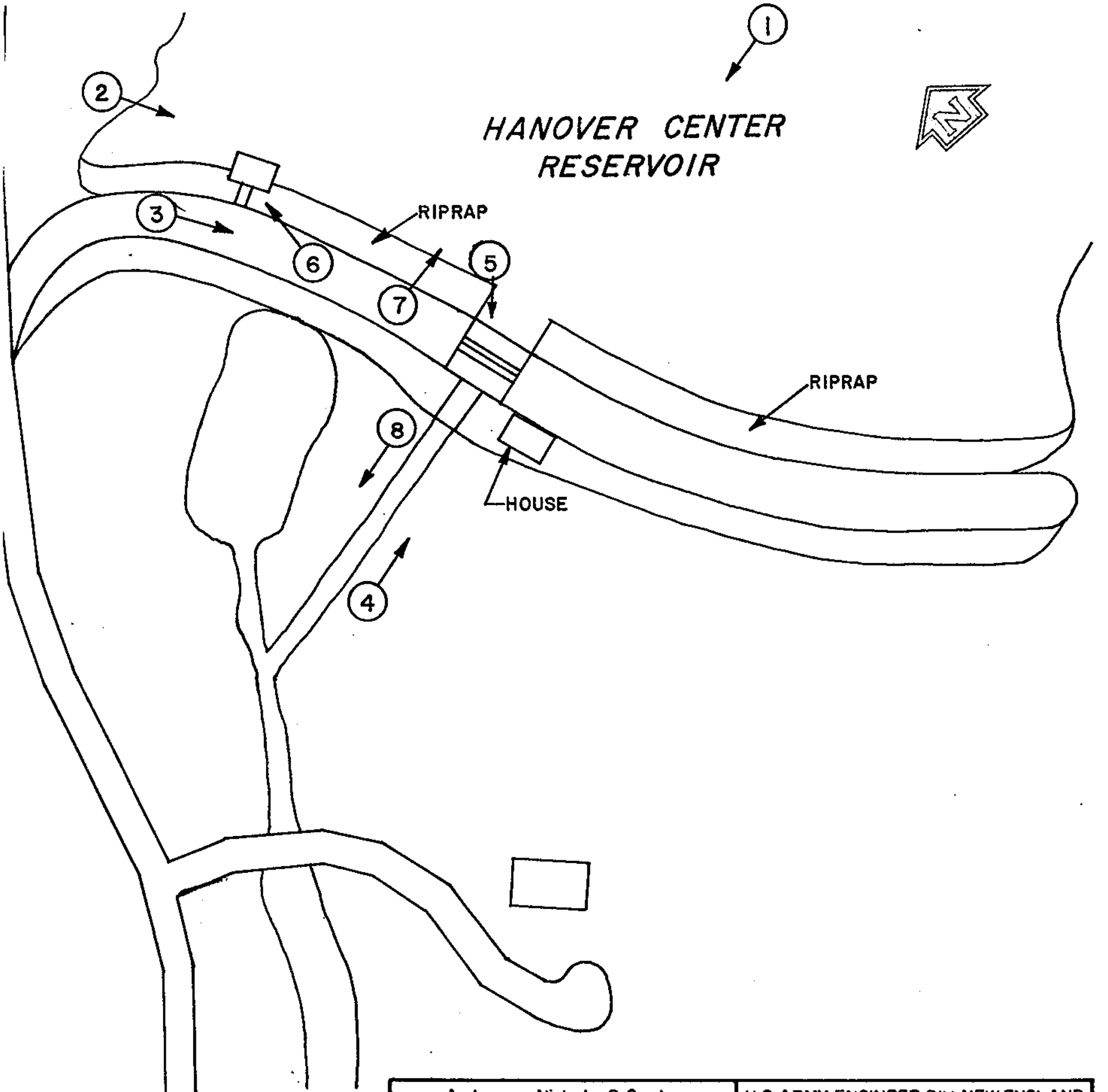
N.BRANCH MINK BROOK NEW HAMPSHIRE

SCALE: NOT TO SCALE

DATE: APRIL 1979

APPENDIX C

PHOTOGRAPHS



Anderson-Nichols & Co., Inc. CONCORD NEW HAMPSHIRE			U.S. ARMY ENGINEER DIV. NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASS.
NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS			
HANOVER CENTER DAM PHOTO INDEX			
HANOVER CENTER			NEW HAMPSHIRE
			SCALE: NOT TO SCALE
			DATE: APRIL, 1979

Figure 2 - Looking south at upstream face of dam.

Figure 3 - Looking south along crest of dam.

Figure 4 - View of downstream face of dam and chute spillway.

Figure 5 - Looking downstream at stoplogs in chute spillway.

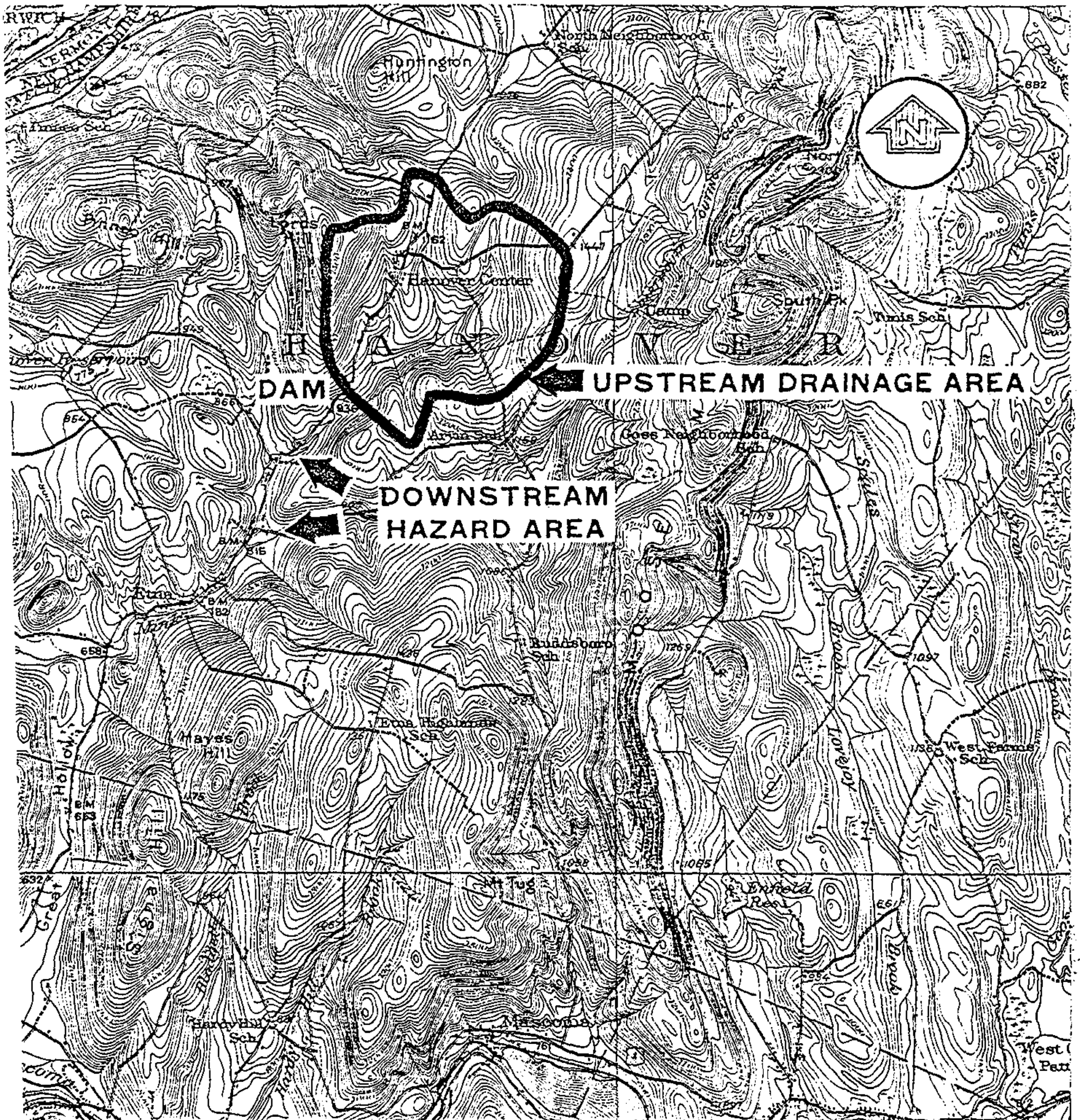
Figure 6 - Looking at gatehouse which contains valve
for controlling discharge into water supply
line and fish pond.

Figure 7 - Looking east at upstream reservoir.

Figure 8 - View of discharge channel below chute spillway outlet.

APPENDIX D

HYDROLOGIC AND HYDRAULIC COMPUTATIONS



TIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

HANOVER CENTER DAM

HANOVER CENTER, NEW HAMPSHIRE

REGIONAL VICINITY MAP

DEPARTMENT OF THE ARMY
W ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS

RSON-NICHOLS & CO., INC. CONCORD, NH

SCALE IN MILES

1 ½ 0 1 2

MAP BASED ON U.S.G.S. 15 MINUTE QUADRANGLE SHEET. MASCOMA, N.H.-VT. 1927.

HYDROLOGY & HYDRAULICS

Hanover Center Dam

Drainage area ≐ 1.85 mi^2
Size classification: Small
Hazard classification: High
Test flood ≐ 1/2 PMF

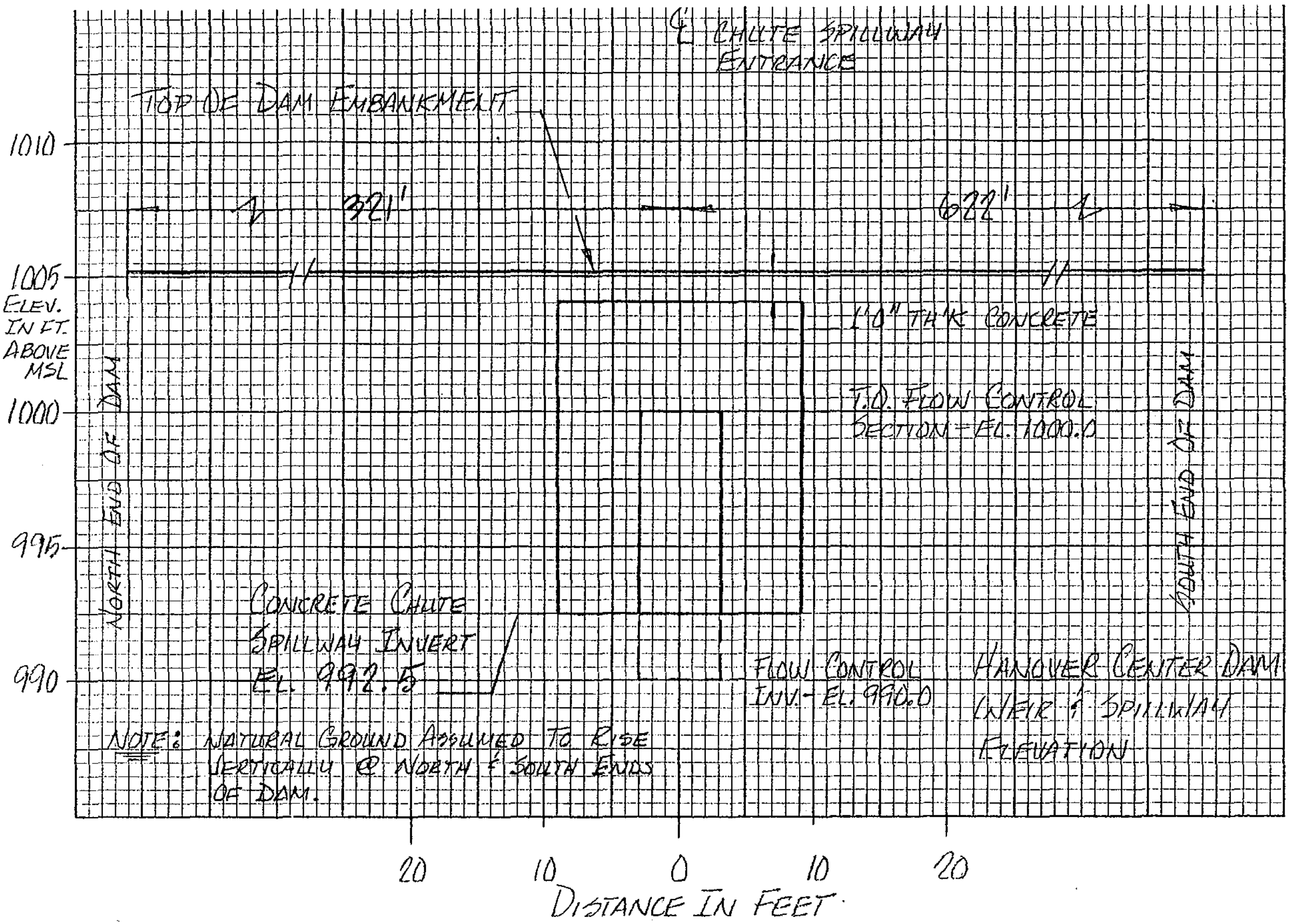
Calculate the PMF using "Preliminary Guidance for Est
Maximum Probable Discharges in Phase I Dam Saf
Investigations, March, 1978."

Average slope of drainage area is 350 ft/mile; therefor
"mountainous" curve will be used to obtain a CSI.

1.85 mi^2 (2550 csm) = 4718 cfs = PMF
1/2 PMF = 4718/2 = 2359 cfs say 1/2 PMF = 2360 c

Determine surcharge height to pass Q_p of 2360
the test flood inflow. To obtain this, a dischar
rating curve must be generated for Hanover Cente
Outflow would occur first through the concrete
spillway that is controlled by stoplogs. Higher
waters would inundate the dam embankment c

In trial ①, assume that the stoplogs have been
removed; in trial ②, assume that the stoplog
are in place.



℄ CHUTE SPILLWAY ENTRANCE
TOP OF DAM EMBANKMENT
1010
1005
1000
995
990
ELEV. IN FT. ABOVE MSL
321'
622'
1'0" TH'K CONCRETE
NORTH END OF DAM
SOUTH END OF DAM
T.O. FLOW CONTROL SECTION - EL. 1000.0
CONCRETE CHUTE SPILLWAY INVERT EL. 992.5
FLOW CONTROL INV. - EL. 990.0
HANOVER CENTER DAM WEIR & SPILLWAY ELEVATION
NOTE: NATURAL GROUND ASSUMED TO RISE VERTICALLY @ NORTH & SOUTH ENDS OF DAM.
20
10
0
10
20
DISTANCE IN FEET

14 Aug 79

Develop a rating curve at the dam...

① Assume: Stoplogs have been removed and obstruc
to flow due to stoplog holding columns is
negligible.

Below elevation 1000.0, low flow controls
Above elevation 1000.0, pressure flow con
Above elevation 1005.0, pressure & weir flo
control.

Along chute spillway, critical depth occur.
point where channel bottom slope change
from mild to steep - el. 990.0.

[▽]Critical depth $\equiv D_c = \left(\frac{Q}{\sqrt{g}\,b}\right)^{2/3}$ for a rect. ch

*Contraction loss may be expressed as:

$$h = \left(\frac{Q}{CMa_2}\right)^2, \text{ where } C = 0.98$$

and $M = \sqrt{\frac{2g}{1-(a_2/a_1)^2}}$, a_1 = u/s X-sect. culvert are
a_2 = d/s X-sect. culvert are

Friction losses are negligible.

▽ From equation 8-29, p. 8-8, Brater & King, Handbook
of Hydraulics.

* From equations 12-13, 14, p. 12-21, Brater & King,
Handbook of Hydraulics.

For low flow conditions, assume a discharge...

$Q = 100$ cfs

$$D_c = \left(\frac{100}{\sqrt{32.2}\,(6.5)}\right)^{2/3} = 1.94'$$

$$M = \sqrt{\frac{2(32.2)}{1-(72/207)^2}} = 8.56\ ,\quad a_1/a_2 = 72/207$$

$$h = \left(\frac{100}{0.98(8.56)72}\right)^2 = 0.03'$$

elevation loss = 2.5'

Reservoir surface elevation = 990.0 + 1.94 + 0.03 + 2.5 ≐ 994.5

$Q = 350$ cfs

$$D_c = \left(\frac{350}{\sqrt{32.2}\,(6.5)}\right)^{2/3} = 4.48'$$

$$M = 8.56$$

$$h = \left(\frac{350}{0.98(8.56)72}\right)^2 = 0.34'$$

elevation loss = 2.5'

Reservoir surface elevation = 990.0 + 4.48 + 0.34 + 2.5 ≐ 997.3

14 Aug 79

$Q = 600$ cfs

$$D_c = \left(\frac{600}{\sqrt{32.2}(6.5)}\right)^{2/3} = 6.42'$$

$$M = 8.56$$

$$h = \left(\frac{600}{0.98(8.56)72}\right)^2 = 0.98'$$

elevation loss = 2.5'

Reservoir surface elevation = 990.0 + 6.42 + 0.98 + 2.5 = 999.9

At a discharge > 600 cfs, pressure flow through the chute spillway occurs.

Pressure flow through a rectangular, concrete cu can be described using the orifice equation:

$Q = Ca\sqrt{2gh}$ where $C = 0.8$*, a ≡ area of opening = and h = u/s. W.S. elev. − elev. @ ℄ o

W.S. Elevation	h (ft)	Q (cfs)
1001.0	6	1022
1002.0	7	1104
1005.0	10	1320
1006.0	11	1384
1007.0	12	1446

* Table 4-11 on p. 4-38, Brater & King, Handbook of Hy

14 Aug 79

Above elev. 1005.0, weir flow occurs over the dam crest;

Use weir equation to compute additional flow over top of dam embankment:

$$Q = CLH^{3/2} \quad \text{where } C = 2.6^{*},\ L = 943'$$

S. Elevation	H (ft)	Q (cfs)	Composite Q (weir + orifice
1006.0	1	2452	3836
1007.0	2	6935	8381

Composite Rating Data (stoplogs removed)

S. Elevation		Q(cfs)
994.5	Low Flow	100
997.3		350
999.9		600
1001.0	Pressure Flow	1022
1002.0		1104
1005.0		1320
1006.0	Pressure & Weir Flow	3836
1007.0		8381

Use the above data to establish a rating curve for the dam (see p. D-10).

* Table 5-3 on p. 5-40, Brater & King, Handbook of Hydraulic

② Assume: Stoplogs are in place - crest elevation 1000.0; critical depth occurs above stoplog crest, which becomes a weir at relatively low flows.

Outflow = 0 when reservoir surface is at elevation 1000.0.

Below elevation 1004.0, weir flow controls. Between elevations 1004.0 and 1005.0, pres flow controls; Above elevation 1005.0, pre. and weir flow control.

Use weir equation, $Q = CLH^{3/2}$, to rate flow over stop crest; $C = 3.4^{*}$, $L = 18'$.

W.S. Elevation	H (ft)	Q (cfs)
1001.0	1	61
1002.0	2	173
1003.0	3	318
1004.0	4	490

With the reservoir surface at elevation 1005.0, pre. flow would occur through the opening above the stoplog crest. To compute pressure flow, use the orifice equation, $Q = Ca\sqrt{2gh}$, where $C = 0.8$ and $a = 18(4) = 72\ ft^2$.

* Estimated with reference to table 5-3, p. 5-40, Brater & King, Handbook of Hydraulics.

∇ Estimated with reference to table 4-11, p. 4-33, Brater & King, Handbook of Hydraulics.

gain, $Q = Ca\sqrt{2gh}$

S. Elevation	H (ft)	Q (cfs)
1005.0	3	801
1006.0	4	924
1007.0	5	1034

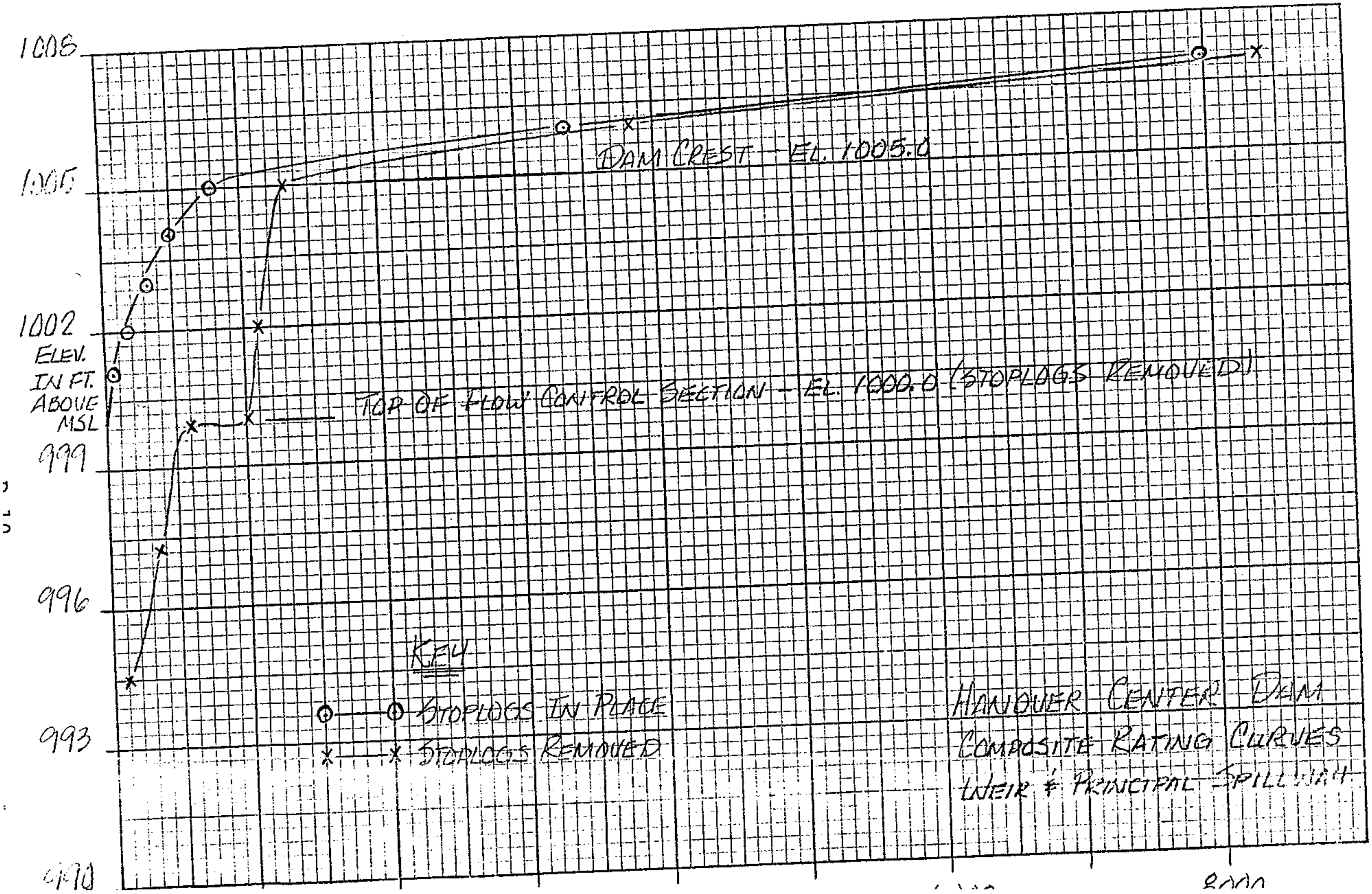
bove elevation 1005.0, weir flow occurs over the am crest; from the computations on p.D-7 were btained the following flows over the top of the am embankment:

S. Elevation	Q (cfs)
1006.0	2452
1007.0	6935

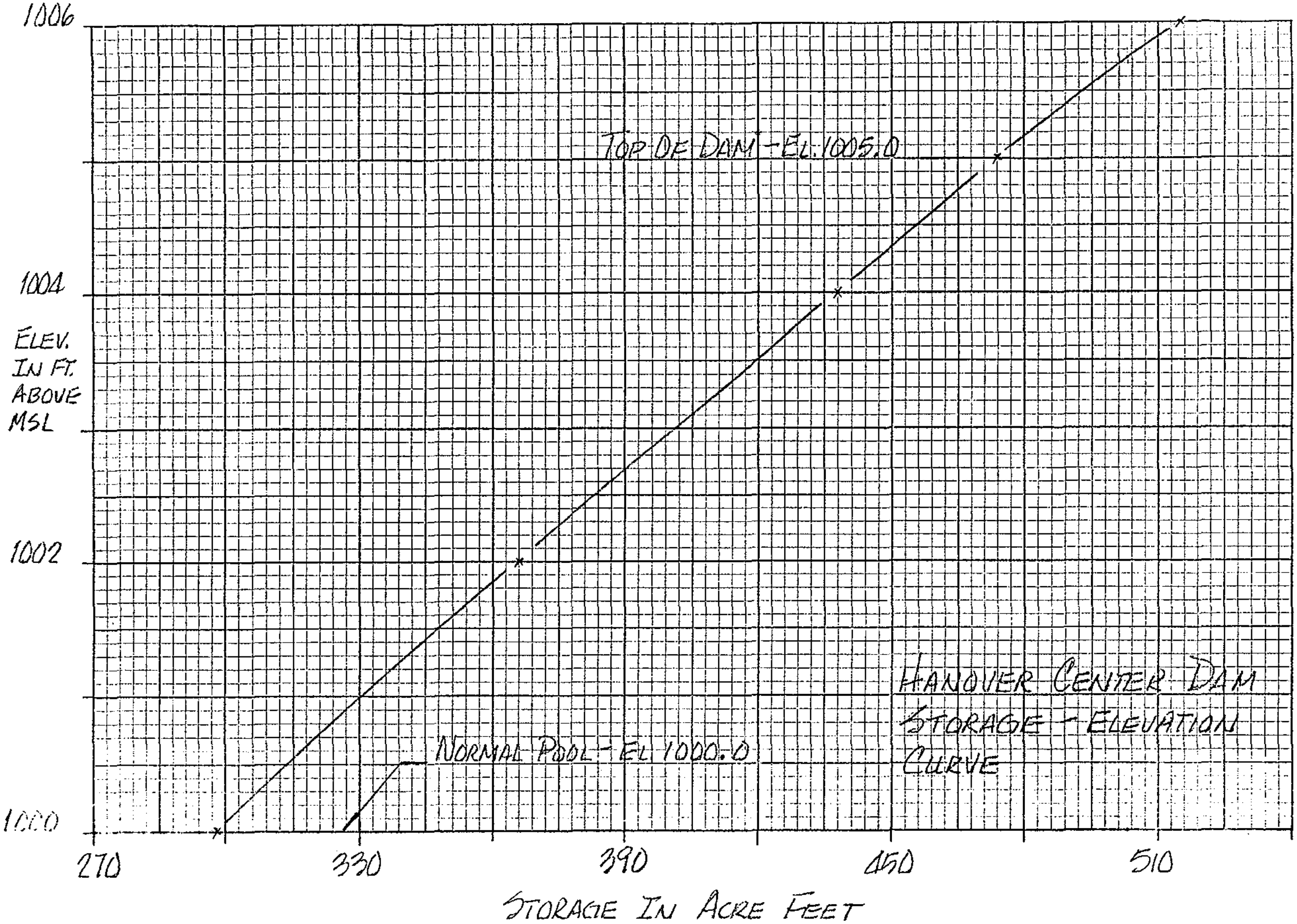
mposite Rating Data (stoplogs in place)

S. Elevation		Q (cfs)
1001.0	Weir Flow	61
1002.0		173
1003.0		318
1004.0		490
1005.0	Pressure Flow	801
1006.0	Pressure & Weir Flow	3376
1007.0		7969

se the above data to establish a rating curve r the dam (see p.D-10).


1008
1005
1002
999
996
993
990
ELEV. IN FT. ABOVE MSL
DAM CREST - EL. 1005.0
TOP OF FLOW CONTROL SECTION - EL. 1000.0 (STOPLOGS REMOVED)
KEY
STOPLOGS IN PLACE
STOPLOGS REMOVED
HANOVER CENTER DAM
COMPOSITE RATING CURVES
WEIR & PRINCIPAL SPILLWAY
8000

14 Aug 79


1006
1004
1002
1000
ELEV. IN FT. ABOVE MSL
TOP OF DAM - EL. 1005.0
NORMAL POOL - EL. 1000.0
HANOVER CENTER DAM STORAGE - ELEVATION CURVE
270
330
390
450
510
STORAGE IN ACRE FEET

14 Aug 79

STORAGE ROUTING - HANOVER CENTER DAM

Assume stoplogs are in place when routing for surcharge storage... Hanover Water Works has no procedure for removing the stoplogs.

Test flood = 1/2 PMF = 2360 cfs, stage = 1005.8*

Normal storage = 298 ac-ft, stage = 1000.0, surface area = 33 acres

Q_{P_1} = 2360 cfs, stage = 1005.8*, storage = 506▽ ac-ft

506 - 298 = 208 ac-ft

$208 \text{ ac-ft} \cdot \frac{1}{1.85 \text{ mi}^2} \cdot \frac{1 \text{ mi}^2}{640 \text{ ac}} \cdot \frac{12 \text{ in.}}{\text{ft}} = 2.11 \text{ in. runoff} \doteq \text{STOR 1}$

$Q_{P_2} = Q_{P_1}\left(1 - \frac{\text{STOR 1}}{9.5}\right) = 2360\left(1 - \frac{2.11}{9.5}\right) = 1836 \text{ cfs}$

@ 1836 cfs, stage = 1005.6*, storage = 497▽ ac-ft

497 - 298 = 199 ac-ft

$199 \text{ ac-ft} \cdot \frac{1}{1.85 \text{ mi}^2} \cdot \frac{1 \text{ mi}^2}{640 \text{ ac}} \cdot \frac{12 \text{ in}}{\text{ft}} = 2.02 \text{ in. runoff} = \text{STO}$

Average of (STOR 1 & STOR 2) ≐ 2.07 in. or 0.173 ft. runoff

$0.173 \text{ ft} \cdot \frac{1.85 \text{ mi}^2}{1} \cdot \frac{640 \text{ ac}}{\text{mi}^2} = 204.8 \text{ ac-ft}$

* See rating curve, p. D-10.
▽ See rating curve, p. D-11.

14 Aug 79

STORAGE ROUTING (CONT.)

'04.8 + 198 = 502.8 ac-ft

@ 502.8 ac-ft, stage = 1005.8 ∇, Q_{P_3} = 2360 cfs *

Q_{P_3} = 2360 cfs = 1/2 PMF = Test flood

. surcharge storage is negligible during the test flood.

Test flood = 1/2 PMF

Test flood discharge = 2360 cfs

Test flood elevation = 1005.8

Top of dam embankment = 1005.0; ∴ dam embankment would be overtopped by 0.8 feet during the test flood.

∇ See rating curve, p. D-11.
* See rating curve, p. D-10.

14 Aug 79

BREACH ANALYSIS – HANOVER CENTER DAM

Purpose: Determine degree of downstream hazard.

Assume: Stoplogs in place; water surface at maximum pool = 1005.0
Upstream riverbed elevation = 980.0

$Q_{p_1} = 8/27\, W_b \sqrt{g}\, Y_0^{3/2}$

where $W_b \equiv$ breach width
$g = 32.2$ ft/sec^2
Y_0 = pool elev. – u/s riverbed elev.

@ Hanover Center Dam:

$W_b = 210^*(0.4) = 84$ ft

$Y_0 = 1005.0 - 980.0 = 25$ ft

$Q_{p_1} = 8/27(84)\sqrt{32.2}\,(25)^{3/2} = 17{,}656$ cfs

Antecedent discharge = 800^{∇} cfs

Total Breach Q = 17,656 + 800 = 18,456, say 18,460 cfs

* Only a fraction (210') of the total length of the dam was multiplied by 40% to obtain the breach width. The structural engineer felt that a breach could occur only along the northern 210' of the dam embankment.

∇ See rating curve, p. D-10.

A 6' diameter CMP culvert is located about 280 feet downstream of the dam. In the event of a breach, it is assumed that the culvert and the sand and gravel road that passes over it would be severely damaged. In effect, a "breach of road" would occur, resulting in little, if any, attenuation of the flood waters released by a breach of dam.

Use a typical cross section of the reach from the toe of the dam to the first concrete culvert encountered, about 530 feet downstream. Develop a discharge rating curve using the Manning Equation:

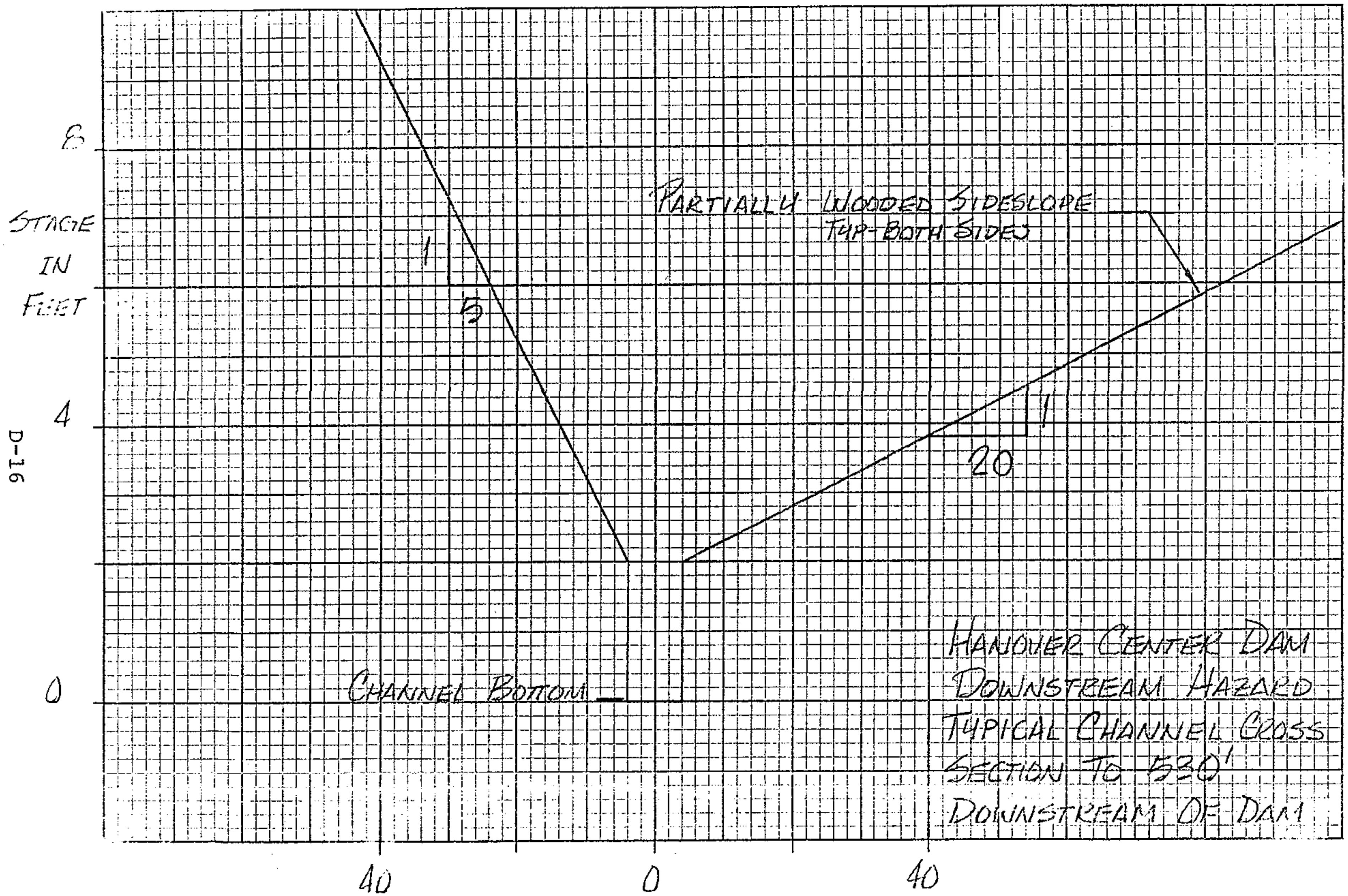
$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$

where $n \equiv$ composite channel roughness coefficient
$A \equiv$ area of section (ft^2)
$R \equiv$ hydraulic radius (ft)
$S \equiv$ slope of reach

. length of reach = 530 ft.
Elevation at downstream toe of dam = 975.0
Elevation at end of reach = 940.0
Slope = 0.066
Composite n = 0.05

$$C = \frac{1.49}{n} S^{1/2} = \frac{1.49}{0.05} (0.066)^{1/2} = 7.66$$

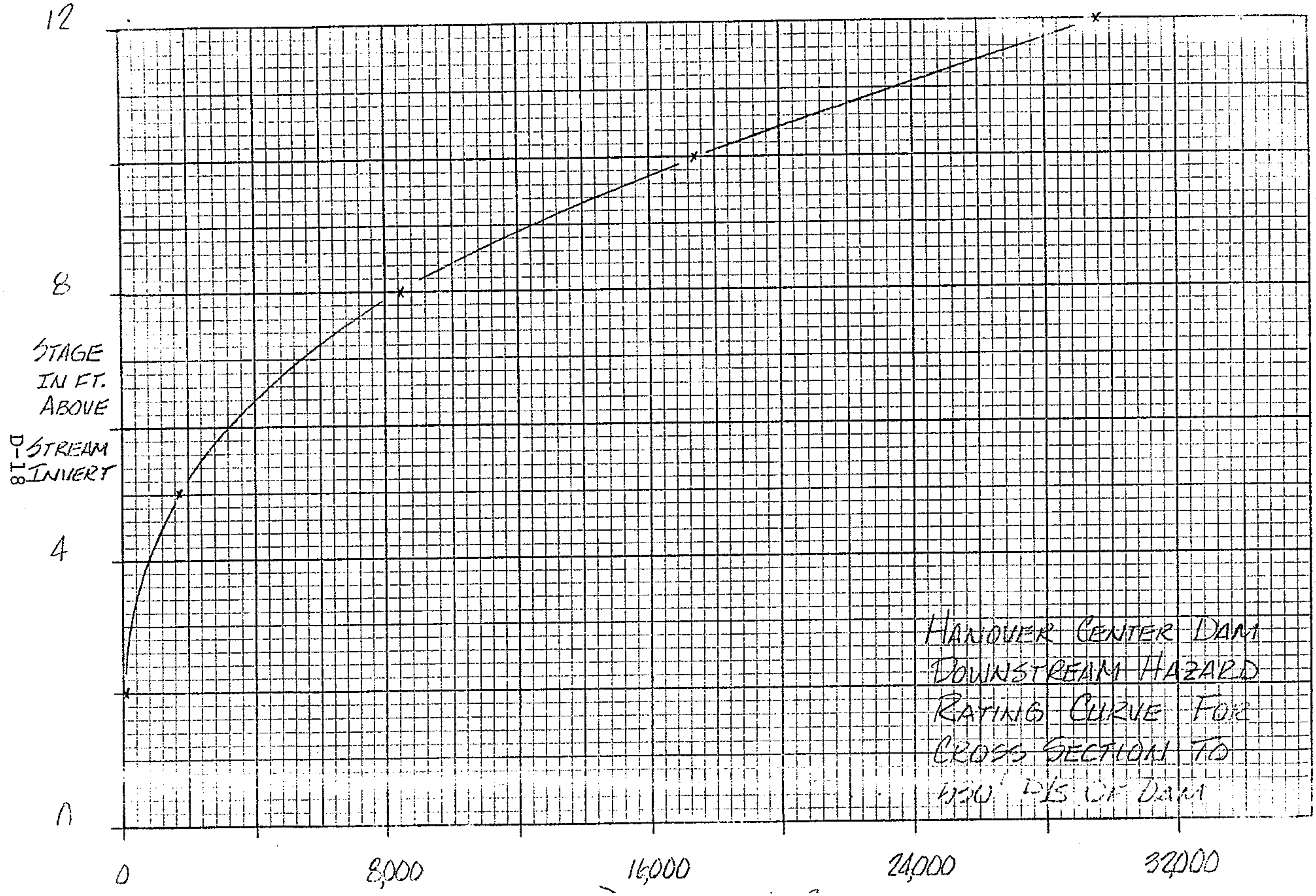
The trials below refer to the cross section on p. D-16.


8
STAGE
IN
FEET
4
0
1
5
PARTIALLY WOODED SIDESLOPE
TYP-BOTH SIDES
1
20
CHANNEL BOTTOM
HANOVER CENTER DAM
DOWNSTREAM HAZARD
TYPICAL CHANNEL CROSS
SECTION TO 530'
DOWNSTREAM OF DAM
40
0
40

REACH ANALYSIS (CONT.) 14 Aug 14

Trial No.	Stage (ft.)	Discharge
1	2	$A = 2(8) = 16\ ft^2$ $WP = 8 + 4 = 12\ ft$ $R = A/WP = 16/12 = 1.33\ ft$ $Q = 7.66(16)(1.33)^{2/3} = 148\ cfs$
2	5	$A = 5(8) + 1/2(5)(3)^2 + 1/2(20)(3)^2 = 152.5\ ft^2$ $WP = 12 + 5.1(3) + 20(3) = 87.3\ ft$ $R = 152.5/87.3 = 1.75\ ft$ $Q = 7.66(152.5)(1.75)^{2/3} = 1696\ cfs$
3	8	$A = 8(8) + 1/2(5)(6)^2 + 1/2(20)(6)^2 = 514\ ft^2$ $WP = 12 + 5.1(6) + 20(6) = 162.6\ ft$ $R = 514/162.6 = 3.16\ ft$ $Q = 7.66(514)(3.16)^{2/3} = 8478\ cfs$
4	10	$A = 10(8) + 1/2(5)(8)^2 + 1/2(20)(8)^2 = 880\ ft^2$ $WP = 12 + 5.1(8) + 20(8) = 212.8\ ft$ $R = 880/212.8 = 4.14\ ft$ $Q = 7.66(880)(4.14)^{2/3} = 17,380\ cfs$
5	12	$A = 12(8) + 1/2(5)(10)^2 + 1/2(20)(10)^2 = 1346\ ft^2$ $WP = 12 + 5.1(10) + 20(10) = 263\ ft$ $R = 1346/263 = 5.12\ ft$ $Q = 7.66(1346)(5.12)^{2/3} = 30,628\ cfs$

Use the above data to develop a discharge rating curve...



12
8
4
0
STAGE IN FT. ABOVE D-STREAM INVERT
0
8,000
16,000
24,000
32,000
HANOVER CENTER DAM
DOWNSTREAM HAZARD
RATING CURVE FOR
CROSS SECTION TO
450' D/S OF DAM

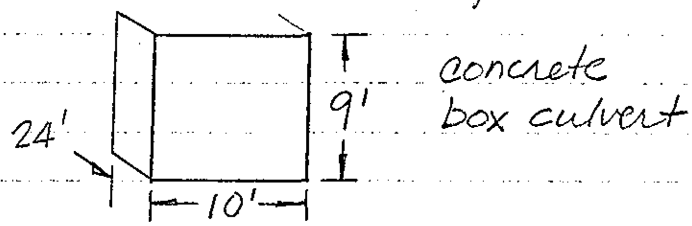
D-18

Referring to the rating curve on p. D-18...

@ Q = 800 cfs (antecedent conditions), stage = 3.2'
@ Q = 18,460 cfs (total breach Q), stage = 10.2'

an increase in stage due to breach of
10.2 - 3.2 = 7.0 feet results.

Analyze the 2nd culvert downstream of Hanover Center Dam...



Use orifice equation to calculate capacity of opening flowing full ... $Q = Ca\sqrt{2gh}$
Upstream stage = 10 feet, C = 0.8*

$Q = 0.8(90)\sqrt{2g(5.5)} = 1355 \text{ cfs} \ll 18{,}460 \text{ cfs}$

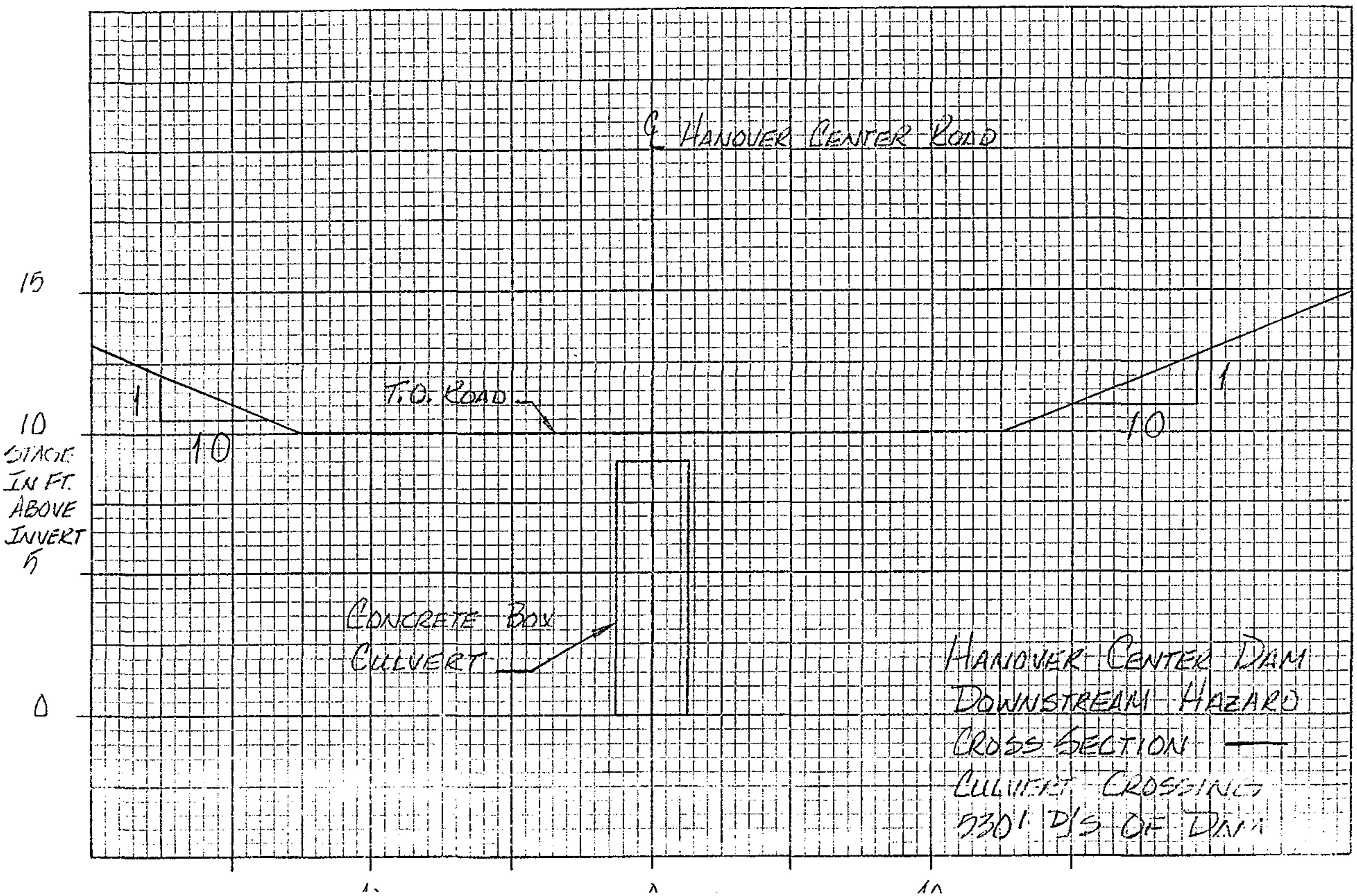
Culvert will not carry total breach Q; ∴ use the Manning Equation to rate flow through the culvert up to a stage of 10 feet. A higher stage will result in weir flow over Hanover Center Road and orifice flow through the concrete box culvert...

$Q = \frac{1.49}{n} AR^{2/3} S^{1/2}$, $K = \frac{1.49}{n} S^{1/2} = \frac{1.49}{0.025} (0.066)^{1/2} = 15.3$

Weir flow, $Q = CLH^{3/2}$, $C = 2.6^{\nabla}$; trials follow on p. D-21.

Note: The breach wave inundates the culvert instantaneously. Therefore, the stage downstream of the culvert would be negligible when calculating flow through the culvert (orifice equation).

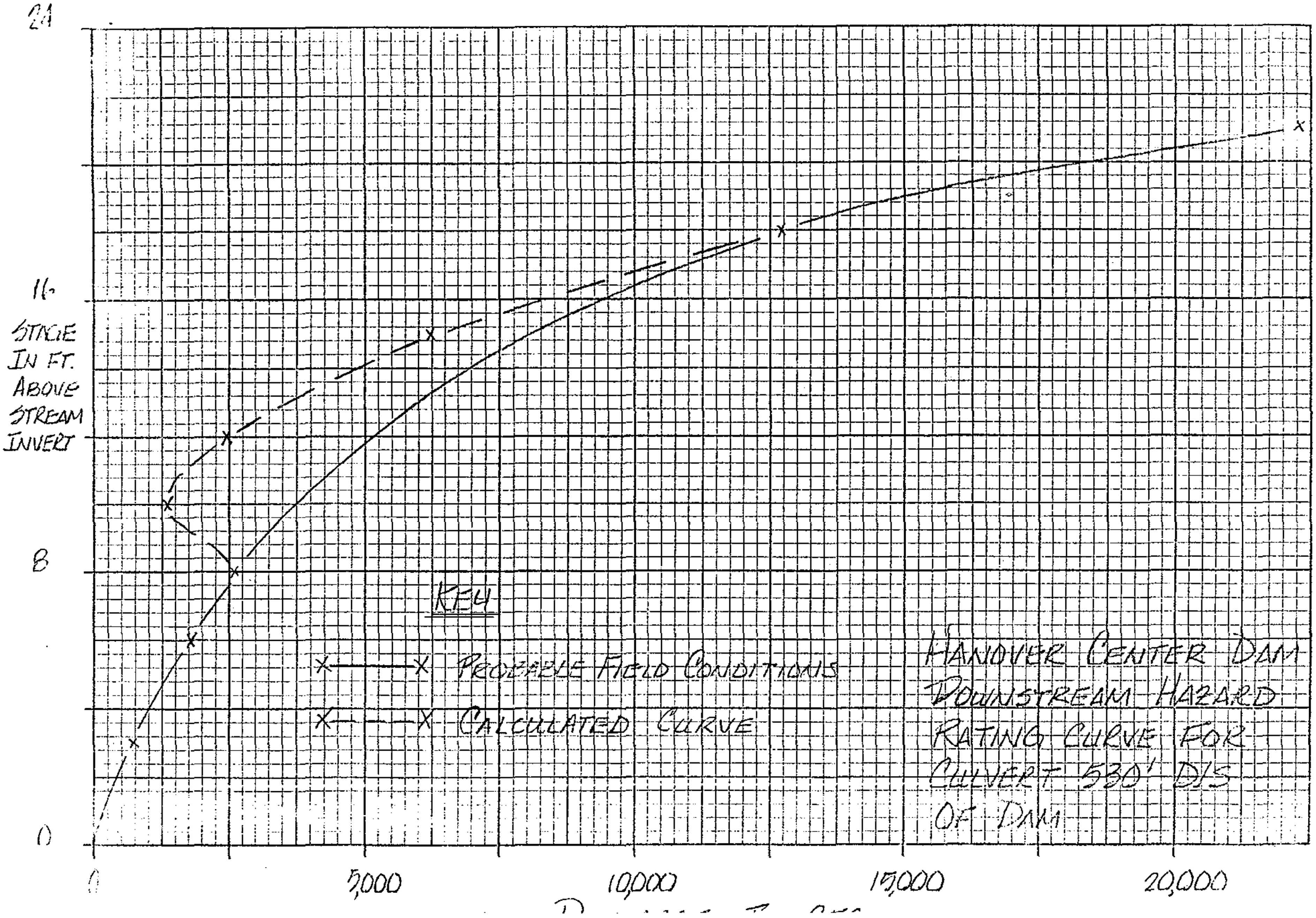
* Estimated from table 4-11, p. 4-38; ▽ Estimated from table 5-3, p. 5-40, Brater and King, Handbook of Hydraulics.



℄ HANOVER CENTER ROAD
15
10
STAGE IN FT. ABOVE INVERT
5
0
1
10
T.O. ROAD
1
10
CONCRETE BOX CULVERT
HANOVER CENTER DAM
DOWNSTREAM HAZARD
CROSS SECTION
CULVERT CROSSING
530' D/S OF DA

Trial No.	Stage (ft)	Discharge
1	3	$A = 10(3) = 30\ ft^2$ $WP = 10 + 2(3) = 16\ ft$ $R = A/WP = 30/16 = 1.88\ ft$ $Q = 15.3(30)(1.88)^{2/3} = 699\ cfs$
2	6	$A = 10(6) = 60\ ft^2$ $WP = 10 + 2(6) = 22\ ft$ $R = 60/22 = 2.73\ ft$ $Q = 15.3(60)(2.73)^{2/3} = 1793\ cfs$
3	8	$A = 10(8) = 80\ ft^2$ $WP = 10 + 2(8) = 26\ ft$ $R = 80/26 = 3.08\ ft$ $Q = 15.3(80)(3.08)^{2/3} = 2591\ cfs$
4	10	$Q = Ca\sqrt{2gh} = 0.8(90)\sqrt{2g(5.5)} = 1355\ cfs$
5	12	$Q = Ca\sqrt{2gh} + CLH^{3/2}$ $Q = 0.8(90)\sqrt{2g(7.5)} + 2.6(100)(2)^{3/2}$ $+ 2(1/2)(2)(10)(2)^{3/2}(2.6) = 2465\ cfs$
6	15	$Q = 0.8(90)\sqrt{2g(10.5)} + 2.6(100)(5)^{3/2}$ $+ 2(1/2)(5)(10)(5)^{3/2}(2.6) = 6233\ cfs$
7	18	$Q = 0.8(90)\sqrt{2g(13.5)} + 2.6(100)(8)^{3/2}$ $+ 2(1/2)(8)(10)(8)^{3/2}(2.6) = 12,713\ cfs$
8	21	$Q = 0.8(90)\sqrt{2g(16.5)} + 2.6(100)(11)^{3/2}$ $+ 2(1/2)(11)(10)(11)^{3/2}(2.6) = 22,267\ cfs$

Use the above data to develop a discharge rating curve ...



24
16
8
0
STAGE IN FT. ABOVE STREAM INVERT
0
5,000
10,000
15,000
20,000
KEY
X——X PROBABLE FIELD CONDITIONS
X— — —X CALCULATED CURVE
HANOVER CENTER DAM
DOWNSTREAM HAZARD
RATING CURVE FOR
CULVERT 530' D/S
OF DAM

14 Aug 79

Referring to the rating curve on p. D-22...

$\therefore Q_A = 800$ cfs, stage = 3.2'

$\therefore Q_B = 18{,}460$ cfs, stage = 20.0'

∴ an increase in stage due to breach of 20.0 - 3.2 = 6.8 feet results. Excessive damage to Hanover Center Road would occur.

---

third culvert is located about 900 feet downstream of the dam. It is of corrugated metal pipe, having cross sectional area of only 20 square feet. herefore, orifice flow through the culvert and weir low over the road would result. The culvert is ocated just upstream of the first group of inhabited tructures encountered downstream of the dam. gain, because the breach wave would arrive at the ulvert instantaneously, the stage downstream of he culvert would be negligible when calculating low through the culvert (orifice equation). Use the eir equation to calculate flow over Hanover enter Road.

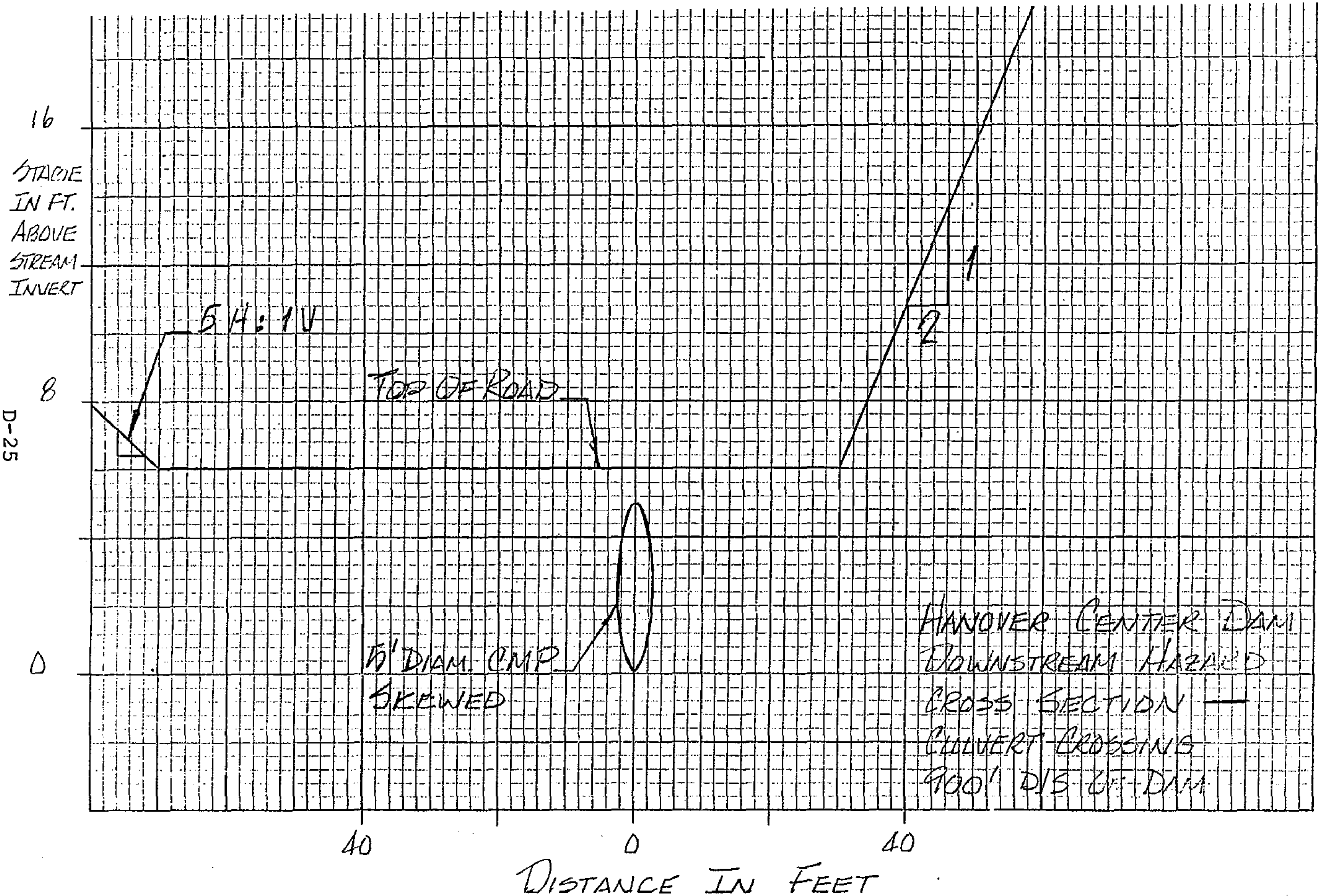
he trials below refer to the cross section on p. D-25.

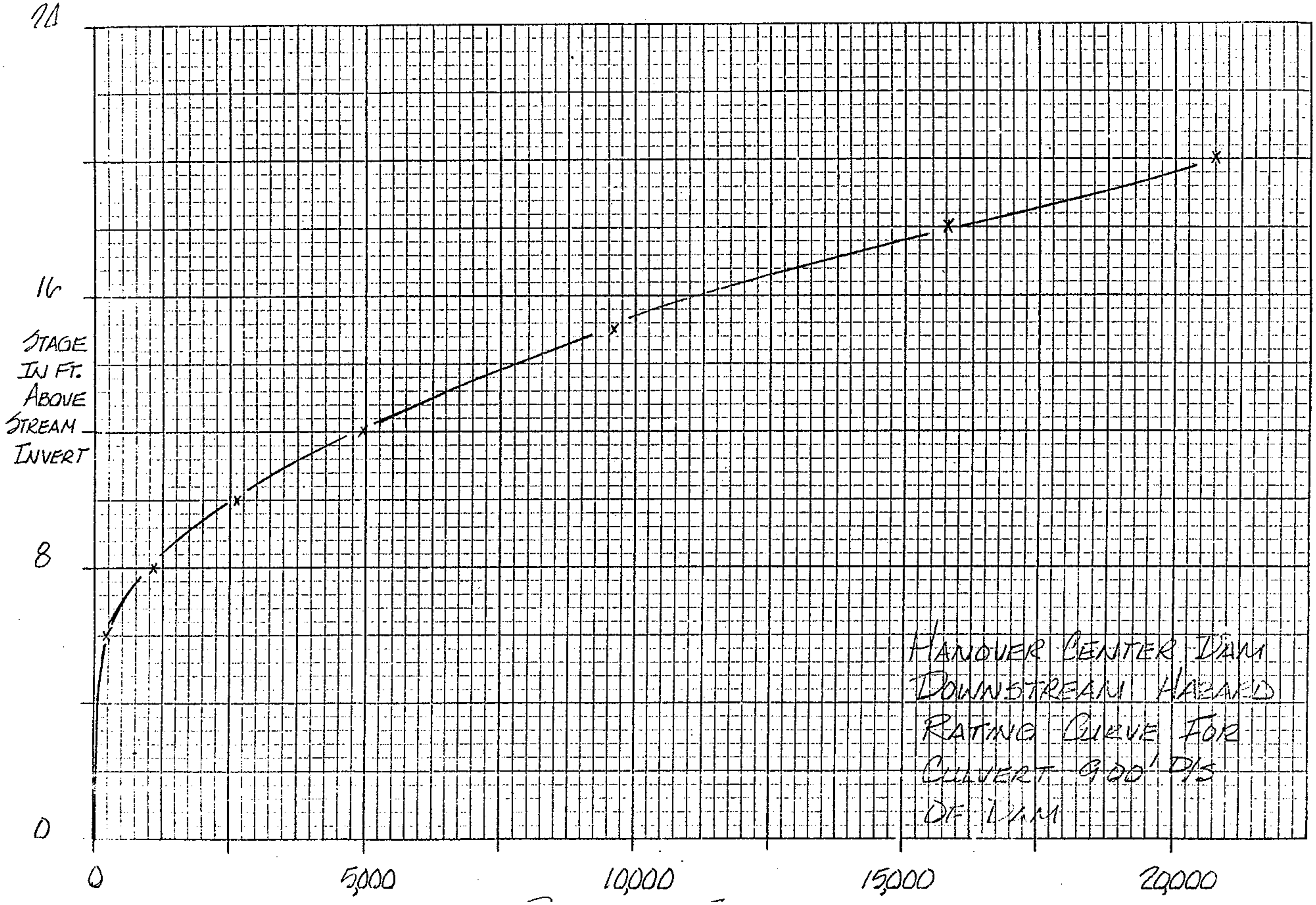
Trial No.	Stage (ft)	Discharge
1	6	$Q = Ca\sqrt{2gh}$, $C = 0.7$ * $Q = 0.7(19.6)\sqrt{2g(3.5)} = 206$ cfs
2	8	$Q = Ca\sqrt{2gh} + C_1LH^{3/2}$, $C_1 = 2.6$ $Q = 0.7(19.6)\sqrt{2g(5.5)} + 2.6(100)(2)$ $+ 2.6(1/2)(2)^2(2)^{3/2} + 2.6(1/2)(2)(5)($ $= 1{,}045$ cfs
3	10	$Q = 0.7(19.6)\sqrt{2g(7.5)} + 2.6(100)(4)^{3}$ $+ 2.6(1/2)(4)(2)(4)^{3/2} + 2.6(1/2)(4)(5)($ $= 2673$ cfs
4	12	$Q = 0.7(19.6)\sqrt{2g(9.5)} + 2.6(100)(6)^{3}$ $+ 2.6(1/2)(6)(2)(6)^{3/2} + 2.6(1/2)(6)(5)($ $= 4{,}963$ cfs
5	15	$Q = 0.7(19.6)\sqrt{2g(12.5)} + 2.6(100)(9)$ $+ 2.6(1/2)(9)(2)(9)^{3/2} + 2.6(1/2)(9)(5)$ $= 9{,}621$ cfs
6	18	$Q = 0.7(19.6)\sqrt{2g(15.5)} + 2.6(100)(12$ $+ 2.6(1/2)(12)(2)(12)^{3/2} + 2.6(1/2)(12)(5)$ $= 15{,}781$ cfs
7	20	$Q = 0.7(19.6)\sqrt{2g(17.5)} + 2.6(100)(14)$ $+ 2.6(1/2)(14)(2)(14)^{3/2} + 2.6(1/2)(14)(5)$ $= 20{,}754$ cfs

Use the above data to develop a discharge rating curve.

* Estimated from table 4-11, p. 4-37, Brater & King, Handbook of Hydraulics.

▽ Estimated from table 5-3, p. 5-40, Brater & King, Handbook of Hydraulics.


16
STAGE IN FT. ABOVE STREAM INVERT
8
0
5 H: 1V
TOP OF ROAD
1
2
5' DIAM. CMP SKEWED
HANOVER CENTER DAM
DOWNSTREAM HAZARD
CROSS SECTION —
CULVERT CROSSING
900' D/S OF DAM
40
0
40
DISTANCE IN FEET


24
16
8
0
STAGE
IN FT.
ABOVE
STREAM
INVERT
0
5,000
10,000
15,000
20,000
HANOVER CENTER DAM
DOWNSTREAM HAZARD
RATING CURVE FOR
CULVERT 900' D/S
OF DAM

14 Aug 74

eferring to the rating curve on p. D-26 ...

$Q_A = 800$ cfs, stage = 7.6'
$Q_B = 16,460$ cfs, stage = 19.0'

an increase in stage due to breach of 19.0 - 7.6 = 11.4 feet would result. The first inhabited structure encountered located just 30 feet downstream of the culvert outlet. Its sill elevation is 8.8 feet above the stream invert. Therefore, the house would be inundated by about 10.2 (19.0-8.8) feet of water after a breach of dam. Severe damage and loss of 2-3 lives could result.

The next two houses downstream are located along a reach whose typical cross section is shown on page D-30. Use the Manning Equation to develop a stage-discharge relationship for this cross section:

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2} \quad \text{where } K = \frac{1.49}{n} S^{1/2}$$

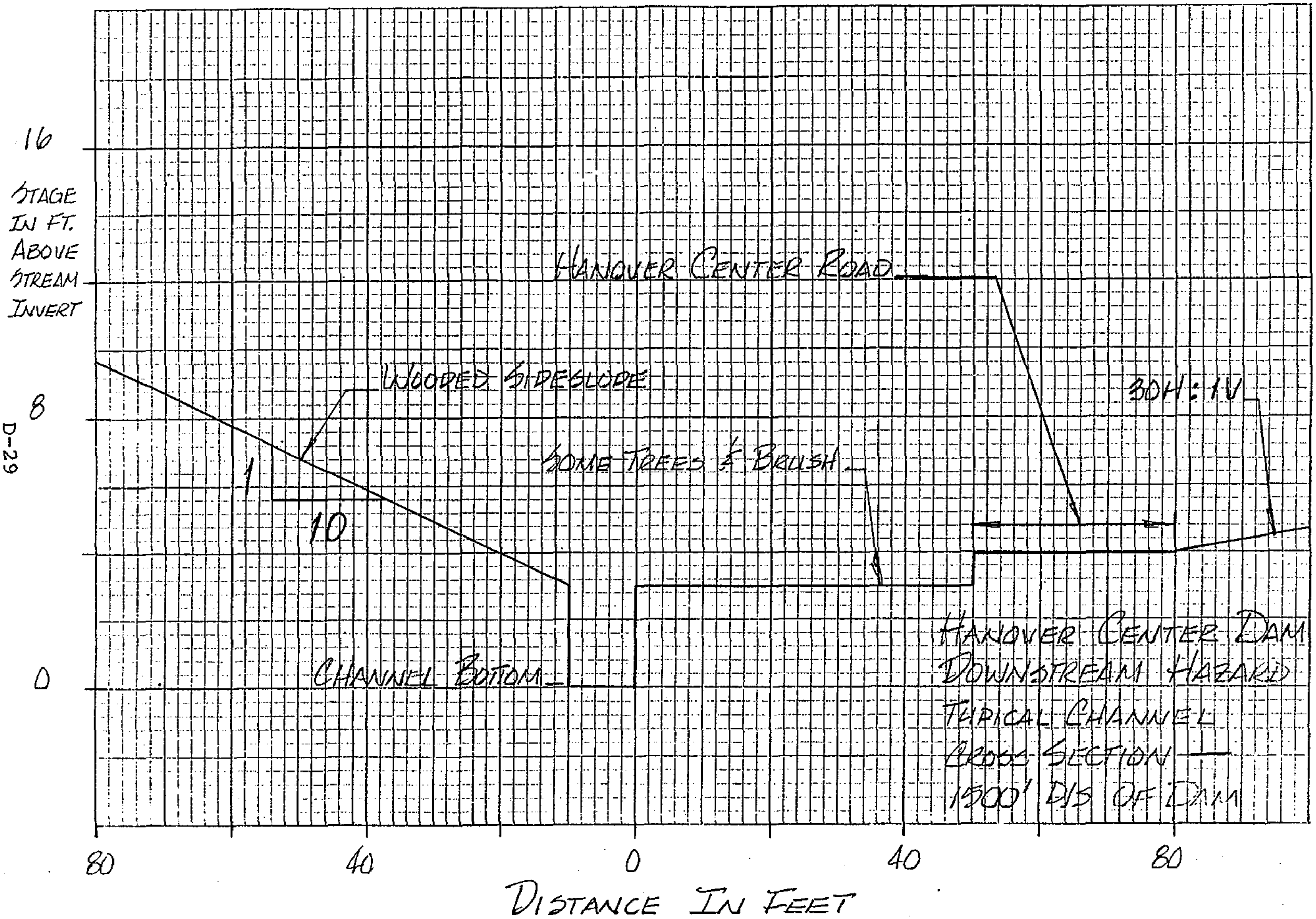
composite $n = 0.05$, $S = \frac{940 - 920}{1000} = 0.02$

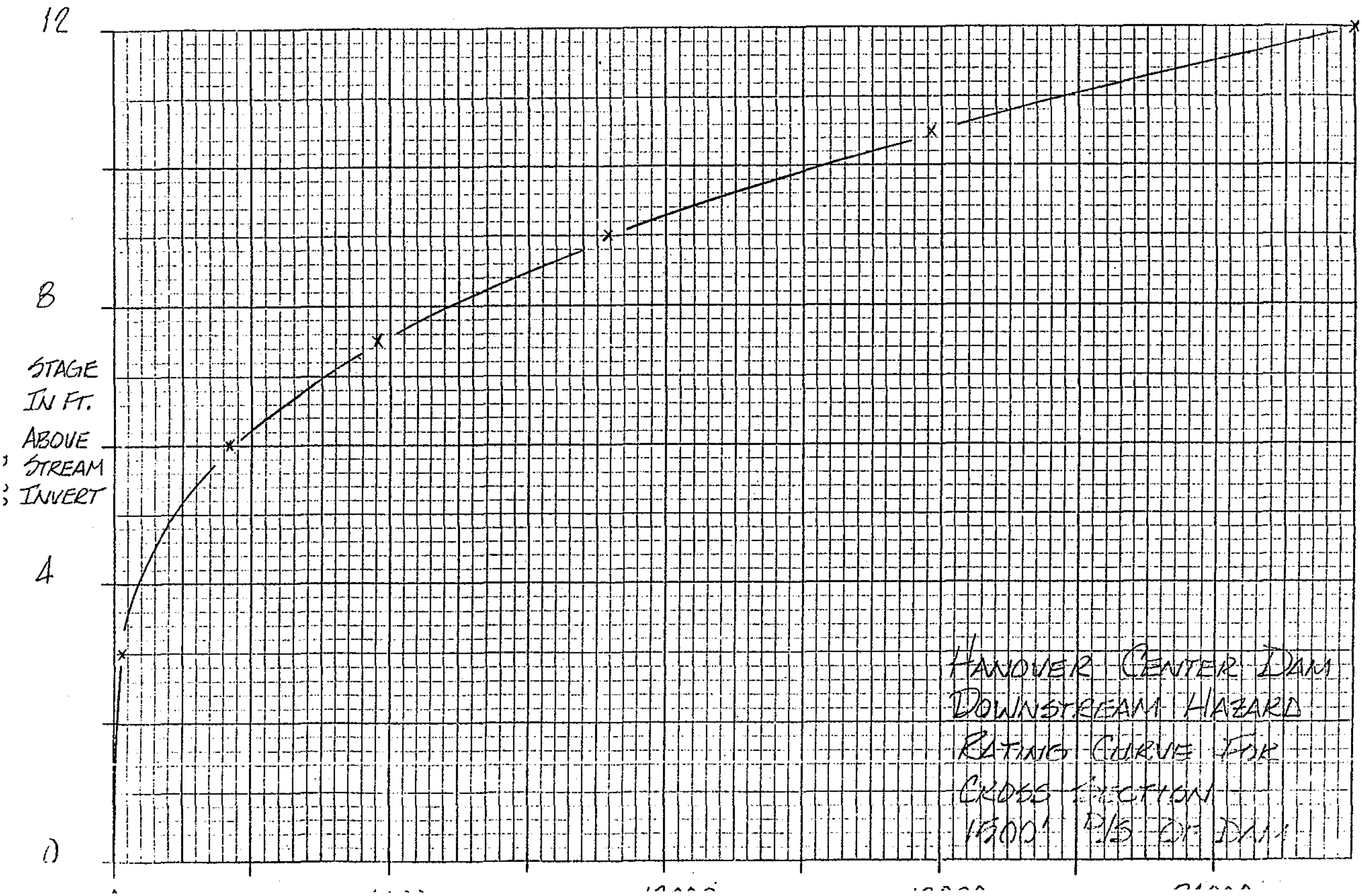
$$K = \frac{1.49}{0.05} (0.02)^{1/2} = 4.21$$

The trials below refer to the cross section on p. D-29.

Trial No.	Stage (ft)	Discharge
1	3	$A = 3(10) = 30\ ft^2$ $WP = 10+6 = 16\ ft$ $R = A/WP = 30/16 = 1.88\ ft$ $Q = 4.21(30)(1.88)^{2/3} = 192\ cfs$
2	6	$A = 6(10) + 1/2(3)^2(10) + 3(50) + 2(30)$ $+ 1/2(2)^2(30) = 375\ ft^2$ $WP = 16 + 3(10) + [50+1+30] + 2(30) = 18$ $R = 375/187 = 2.01\ ft$ $Q = 4.21(375)(2.01)^{2/3} = 2{,}513\ cfs$
3	7.5	$A = 7.5(10) + 1/2(4.5)^2(10) + 4.5(50) + 3.5(30)$ $+ 1/2(3.5)^2(30) = 690\ ft^2$ $WP = 16 + 4.5(10) + 81 + 3.5(30) = 247$ $R = 690/247 = 2.79\ ft$ $Q = 4.21(690)(2.79)^{2/3} = 5{,}753\ cfs$
4	9	$A = 9(10) + 1/2(6)^2(10) + 6(50) + 5(30)$ $+ 1/2(5)^2(30) = 1095\ ft^2$ $WP = 16 + 6(10) + 81 + 5(30) = 307\ ft$ $R = 1095/307 = 3.57\ ft$ $Q = 4.21(1095)(3.57)^{2/3} = 10{,}759\ cfs$
5	10.5	$A = 10.5(10) + 1/2(7.5)^2(10) + 7.5(50) + 6.5$ $+ 1/2(6.5)^2(30) = 1590\ ft^2$ $WP = 16 + 7.5(10) + 81 + 6.5(30) = 36$ $R = 1590/367 = 4.33\ ft$ $Q = 4.21(1590)(4.33)^{2/3} = 17{,}761\ cf$
6	12	$A = 12(10) + 1/2(9)^2(10) + 9(50) + 8(30)$ $+ 1/2(8)^2(30) = 2175\ ft^2$ $WP = 16 + 9(10) + 81 + 8(30) = 427$ $R = 2175/427 = 5.09\ ft$ $Q = 4.21(2175)(5.09)^{2/3} = 27{,}065\ c$

Use the above data to develop a discharge rating curve


16
8
0
STAGE IN FT. ABOVE STREAM INVERT
HANOVER CENTER ROAD
WOODED SIDESLOPE
30H : 1V
SOME TREES & BRUSH
1
10
CHANNEL BOTTOM
HANOVER CENTER DAM
DOWNSTREAM HAZARD
TYPICAL CHANNEL
CROSS SECTION
1500' D/S OF DAM
80
40
0
40
80
DISTANCE IN FEET


12
8
4
0
STAGE IN FT. ABOVE STREAM INVERT
HANOVER CENTER DAM
DOWNSTREAM HAZARD
RATING CURVE FOR
CROSS SECTION
1500' D/S OF DAM

AFS
14 Aug 79

Referring to the rating curve on p. D-30...

@ Q_A = 800 cfs, stage = 4.4'

@ Q_B = 18,460 cfs, stage = 10.6'

∴ an increase in stage due to a breach is 10.6 - 4.4 = 6.2 feet. There are two houses along this reach whose sill elevations are approximately 5.7 feet above the stream invert. Therefore, these houses would be inundated by about 4.9 (10.6 - 5.7) feet of water after a breach of dam. Severe damage and loss of 4-6 lives could result.

A second populated area is located about 2600 feet downstream of the dam. Use the Manning Equation to develop a stage-discharge relationship for the reach as described by the cross section on p. D-33.

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}, \quad K = \frac{1.49}{n} S^{1/2}$$

composite $n = 0.05$, $S = \frac{920 - 880}{1200} = 0.033$

$$K = \frac{1.49}{0.05} (0.033)^{1/2} = 5.41$$

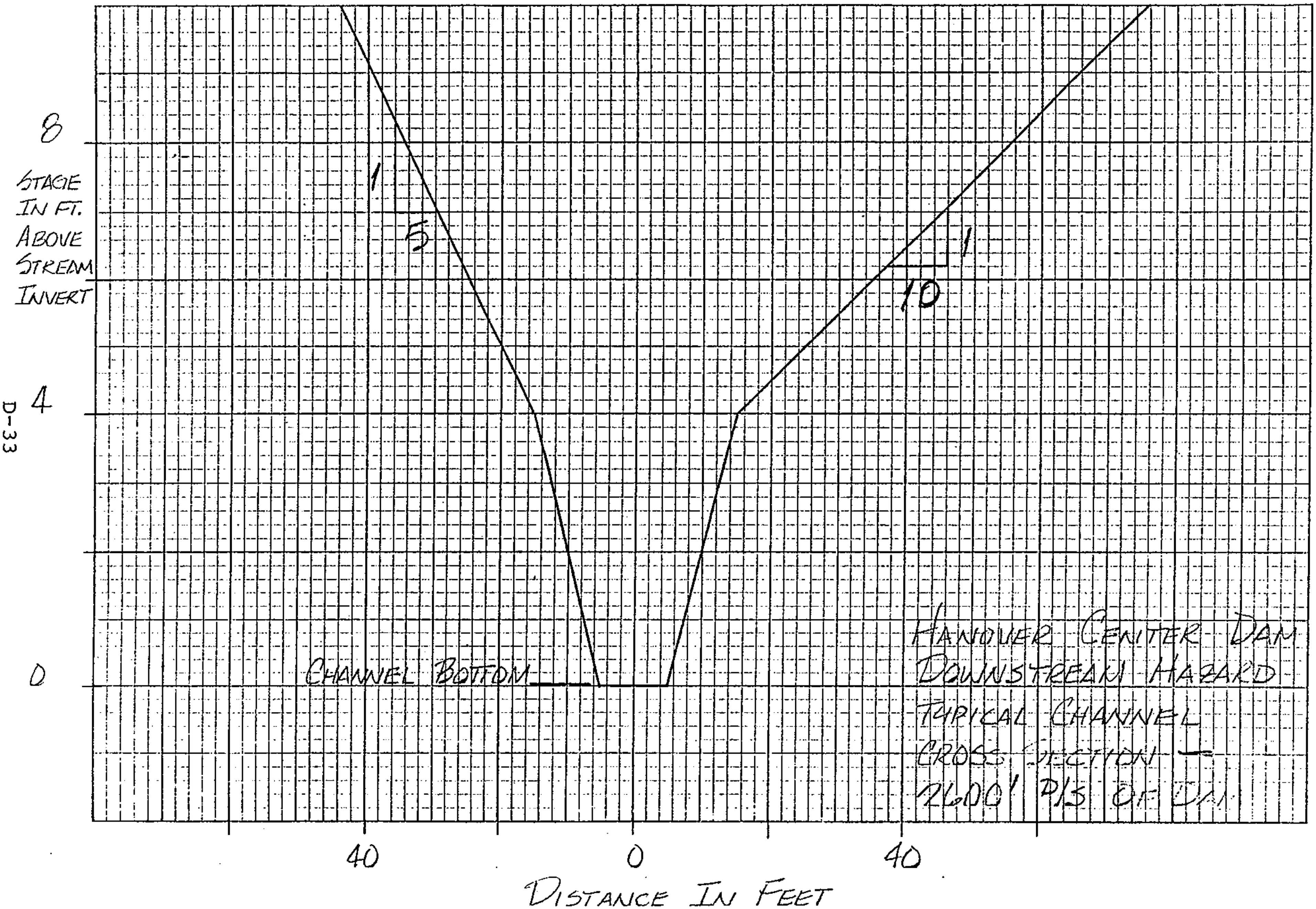
The trials below refer to the cross section on p. D-33.

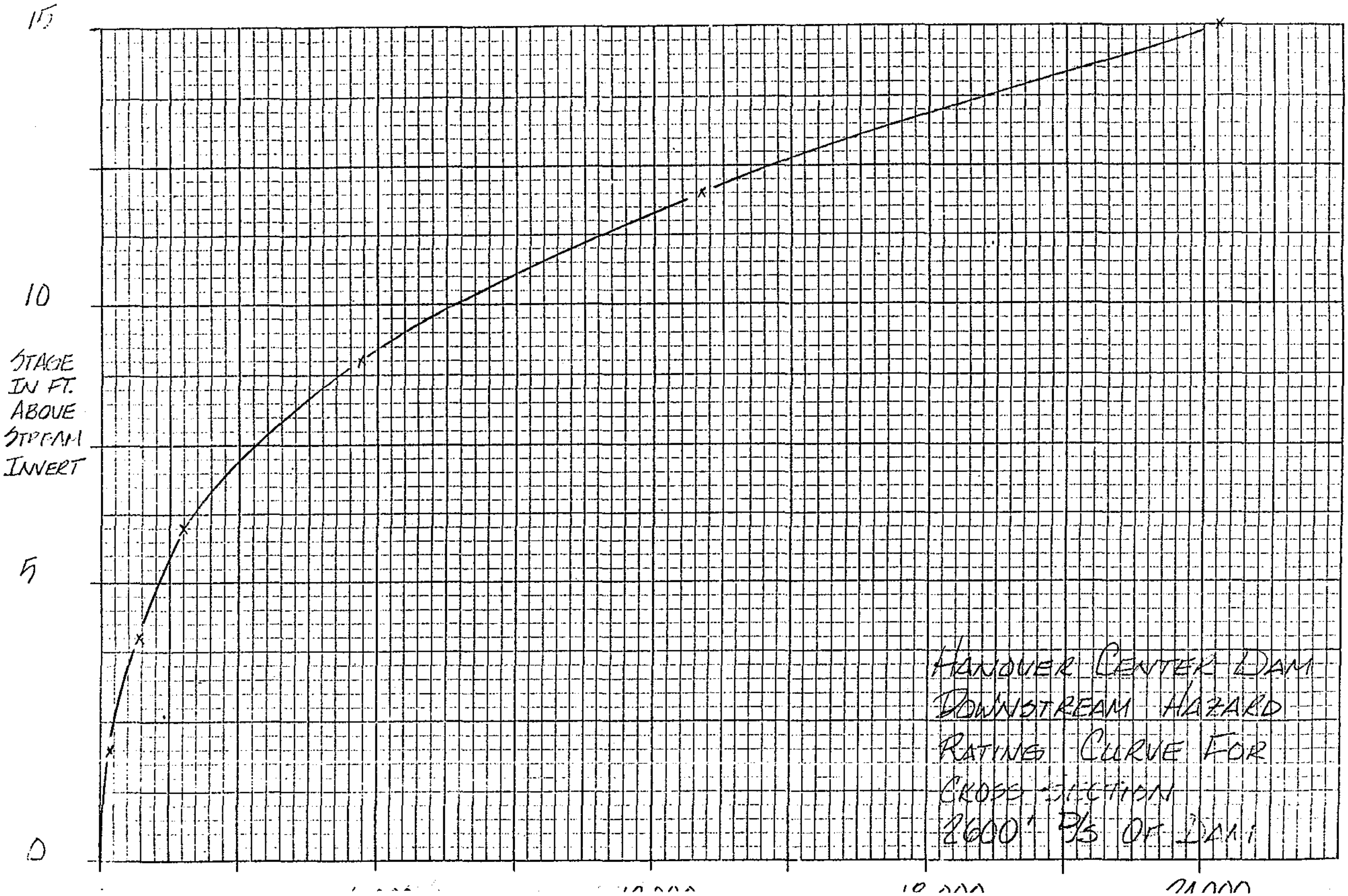
BREACH ANALYSIS (CONT.)

ABS
14 Aug 79

Trial No.	Stage (ft)	Discharge
1	2	$A = 1/2(2)[10+20] = 30 ft^2$ $WP = 10 + 10.8 = 20.8$ ft $R = A/WP = 30/20.8 = 1.44$ ft $Q = 5.41(30)(1.44)^{2/3} = 207$ cfs
2	4	$A = 1/2(4)[10+30] = 80 ft^2$ $WP = 10 + 21.6 = 31.6$ ft $R = 80/31.6 = 2.53$ ft $Q = 5.41(80)(2.53)^{2/3} = 803$ cfs
3	6	$A = 80 + 2(30) + 1/2(2)^2(5) + 1/2(2)^2(10)$ $WP = 31.6 + 2(5.1) + 2(10) = 61.8$ ft $R = 170/61.8 = 2.75$ ft $Q = 5.41(170)(2.75)^{2/3} = 1804$ c
4	9	$A = 80 + 5(30) + 1/2(5)^2(5) + 1/2(5)^2(10)$ $WP = 31.6 + 5(5.1) + 5(10) = 107.1$ ft $R = 417.5/107.1 = 3.90$ ft $Q = 5.41(417.5)(3.90)^{2/3} = 5591$ cfs
5	12	$A = 80 + 8(30) + 1/2(8)^2(5) + 1/2(8)^2(10)$ $WP = 31.6 + 8(5.1) + 8(10) = 152.4$ ft $R = 800/152.4 = 5.25$ ft $Q = 5.41(800)(5.25)^{2/3} = 13,057$
6	15	$A = 80 + 11(30) + 1/2(11)^2(5) + 1/2(11)^2($ $WP = 31.6 + 11(5.1) + 11(10) = 197.7$ ft. $R = 1290/197.7 = 6.53$ ft $Q = 5.41(1290)(6.53)^{2/3} = 24,351$

Use the above data to develop a discharge rating cu


8
STAGE
IN FT.
ABOVE
STREAM
INVERT
4
0
1
5
1
10
CHANNEL BOTTOM
HANOVER CENTER DAM
DOWNSTREAM HAZARD
TYPICAL CHANNEL
CROSS SECTION —
2600' D/S OF DAM
40
0
40
DISTANCE IN FEET


15
10
5
0
STAGE IN FT. ABOVE STREAM INVERT
HANOVER CENTER DAM
DOWNSTREAM HAZARD
RATING CURVE FOR
CROSS SECTION
2600' D/S OF DAM

ATS III
14 Aug 79

Referring to the discharge rating curve on p. D-34...

Q_A = 800 cfs, stage = 4.0'

Q_B = 18,460 cfs, stage = 13.6'

An increase in stage due to breach of 13.6 - 4.0 = 9.6 feet would result. There are six houses along this reach whose sill elevations are approximately 7 feet above the stream invert. These houses would be inundated by about 6.6 (13.6 - 7.0) feet of water after a breach of dam. Severe damage and loss of 6-10 lives could result.

The potential damage to property and danger to human life are summarized as follows:

If a breach at top of dam occurred, a sand and gravel driveway would probably be washed out. Hanover Center Road would be inundated at two brook crossings, probably resulting in severe damage to the road. Seven houses would be inundated with more than six feet of water, causing excessive property damage and endangering more than ten lives. Therefore, Hanover Center Dam has been classified as High Hazard.

LOW LEVEL OUTLET CAPACITY

Assume: Pool elevation = 1005.0 (top of dam)
Pipe invert elevation = 979.5
10-in. I.D. cast iron pipe, 25-foot sectio

Use: Orifice equation, $Q = Ca\sqrt{2gh}$
$a \equiv$ cross sectional pipe area = 0.55 ft²
$h \equiv$ head differential = $1005.0-(979.5+(\frac{10}{12}/2)) = 25.1$ ft
$C = ?$

Find: C, coefficient of discharge

$$C = C_p/A_p/\sqrt{2g} \quad , \quad C_p^{*} = A_p\sqrt{\frac{2g}{1+K_L+K_f L_p}}$$

$K_L \equiv$ entrance loss = 0.5 ▽

$K_F \equiv$ friction loss = 0.06 ●

$n \equiv$ roughness coefficient = 0.016

$A_p \equiv$ area of pipe = 0.55 ft²

$L_p \equiv$ length of pipe = 25 ft

$C_p \equiv$ coefficent of discharge incorporating A_p & 2.

$C \equiv$ coefficient of discharge

* From equation 3-12, p. 3-24, Soil Conservation Servic Field Engineering Manual.

▽ Figure D-1, p. 639, Schwab, Frevert, ..., Soil and W Conservation Engineering.

● Table D.1, p. 641, Schwab, Frevert, ..., Soil and Water Conservation Engineering.

LOW LEVEL OUTLET CAPACITY (CONT.)

$$= A_p \sqrt{\frac{2g}{1+K_L+K_f L_p}} = 0.55\sqrt{\frac{64.4}{1+0.5+(0.06)(25)}}$$

$$= 2.55$$

$$= C_p / A_p / \sqrt{2g} = 2.55/0.55/\sqrt{64.4}$$

$$= 0.58$$

$$= C a \sqrt{2gh} \; *$$

$$= 0.58(0.55)\sqrt{2(g)(25.1)} = \underline{\underline{13 \text{ cfs}}}$$

Equation 4-10, p. 4-10, Brater & King, Handbook of Hydraulics.

APPENDIX E

INFORMATION AS CONTAINED IN THE NATIONAL INVENTORY OF DAMS

NH	51	NED	NH	009	02				HANOVER CENTER RESERVOIR DAM	4342.7	7212.1	27APR79

POPULAR NAME	NAME OF IMPOUNDMENT
HANOVER CENTER DAM	HANOVER CENTER RESERVOIR

REGION	BASIN	RIVER OR STREAM	NEAREST DOWNSTREAM CITY-TOWN-VILLAGE	DIST FROM DAM (MI.)	POPULATION
01	08	NORTH BRANCH MINK BROOK	HANOVER(VILLAGE OF ETNA)	2	1000

TYPE OF DAM	YEAR COMPLETED	PURPOSES	STRUCTURAL HEIGHT (FT.)	HYDRAULIC HEIGHT (FT.)	IMPOUNDING CAPACITIES MAXIMUM (ACRE-FT.)	IMPOUNDING CAPACITIES NORMAL (ACRE-FT.)	DIST	OWN	FED R	PRV/FED	SCS A	VER/DATE
PGRE	1962	S	30	30	476	298	NED	N	N	N	N	

REMARKS

D/S HAS	SPILLWAY CREST LENGTH	SPILLWAY TYPE	SPILLWAY WIDTH (FT.)	MAXIMUM DISCHARGE (FT.)	VOLUME OF DAM (CY)	POWER CAPACITY INSTALLED (MW)	POWER CAPACITY PROPOSED (MW)	NAVIGATION LOCKS NO	LENGTH (FT.)	WIDTH (FT.)	LENGTH (FT.)	WIDTH (FT.)	LENGTH (FT.)	WIDTH (FT.)	LENGTH (FT.)	WIDTH (FT.)
1	943	C	18	1320												

OWNER	ENGINEERING BY	CONSTRUCTION BY
HANOVER WATER WORKS CO	ANDERSON-NICHOLS CO,INC	HANOVER WATER WORKS CO

REGULATORY AGENCY DESIGN	CONSTRUCTION	OPERATION	MAINTENANCE
NH WATER RES BD	NH WATER RES BD	NH WATER RES BD	NH WATER RES BD

INSPECTION BY	INSPECTION DATE DAY MO YR	AUTHORITY FOR INSPECTION
ANDERSON-NICHOLS + COMPANY INC	09NOV78	PUBLIC LAW 92-367 AUG 1972

REMARKS
33-STOPLOGS REMOVED